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HARNESSING THE COLUMBIA RIVER

THE GRAND COULEE DAM AND ITS GEOGRAPHICAL SETTING

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OF all the great single structures in the world so far attempted, the Grand Coulee Dam on the Columbia River will be the greatest. Two and a half times the volume of Boulder Dam, its completed bulk will be thrice that of the Great Pyramid. Boulder Dam and the Tennessee Valley Project have already been described in this *Journal* (86 (1935) 498–504, and 89 (1937) 393–408). The Columbia Basin Irrigation Project was the subject of a brief well-illustrated statement written when the whole scheme was still in an early state (64 (1924) 470–7).

The Columbia is the greatest potential source of usable energy of any river on the North American continent. It is 1200 miles in length, drains an area of almost 260,000 square miles and falls 1288 feet in the 610 miles of its lower course between the Canadian border and tidewater, 140 miles from its mouth on the Pacific coast. The plan to tap this water and energy at the Grand Coulee Dam is the key factor in the wider Columbia Basin Reclamation Project. It aims to bring under cultivation 1800 square miles of land, to regulate the river flow, to develop an annual power-output of over 8000 million kilowatt-hours with provision for half as much again as a secondary output, and eventually to wrest from the river nine-tenths of its energy between the Canadian border and the Pacific Ocean. Plans have been made for settling a population of a quarter of a million in the irrigated area of a district hitherto supporting five per square mile and with an average annual precipitation of less than 10 inches.

The geological setting which makes the project feasible is the result of an Ice-age story precise details of which were for some years a matter of debate. Since 1933 excavations for the dam abutments and for gravel-pits to supply the giant concrete-mixers have brought to light shreds of evidence which can now be pieced together into a connected account of late Pleistocene glacial history.[1] As shown in the sketch-map (Fig. 2), the Columbia rises in the

[1] R. F. Flint and W. H. Irwin, "Glacial Geology of Grand Coulee Dam," *Geol. Soc. Amer. Bull.*, vol. 50 (1939), pp. 661–680.

Canadian Rockies 100 miles south-west of Calgary and strikes south in a deep fault-trench across the border of the United States. When level with Spokane it turns abruptly west, in a big double bend which takes it W.N.W. to the point where the Okanogan (pronounced Okanógan) enters from across the Canadian line, before turning south again. At this confluence a glacier from the Okanogan valley dammed the main gorge, ponding the water up river into a lake which found an outlet round the edge of the ice. Further glacial advance completely blocked the gorge of the Columbia, damming its waters to still greater depth, backing them farther upstream and forcing them to find a new high-level spillway along a depression across the plateau basalts, thus short-circuiting part of the river loop (Fig. 1A). To-day the Columbia above the dam drains a basin of 74,000 square miles, with a total run-off of 79,000,000 acre-feet, and delivering an average of 109,000 cubic feet of water at the dam each second. How much greater it was when the glaciers were melting can

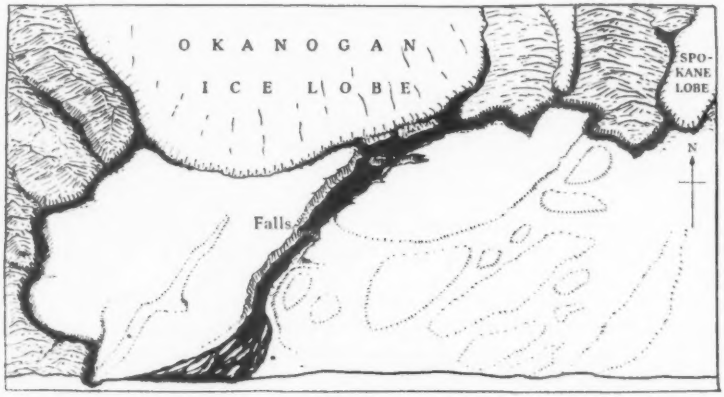


Fig. 1A

only be guessed. It was enough however to remove 40 cubic miles of solid rock, leaving a 50-mile canyon from 1 to 5 miles wide, cut down through 800 feet of basalt into the underlying granite foundations. Using the old French name for a dry river channel the early settlers called this canyon the Grand Coulee (Plate 1).

During one extreme fluctuation the ice pressed still farther forward, blocking the Grand Coulee itself and forcing the water to escape by a series of smaller coulees that scar the basalt uplands farther upstream in the area of the Channelled Scablands (Fig. 1B). As the ice melted, the lower levels of earlier overflow were uncovered one after the other, till the river finally found and scoured out its original channel, leaving the Grand Coulee as an abandoned spillway, high and dry, 653 feet above the present river-level. The succession of changes outlined above is actually simpler than the full story unravelled by Flint and Irwin from the complex mass of delta-carved and massive silts, sands, gravel, and glacial drift near the dam site.

J. H. Bretz,[1] who first gave the Coulee its deserved prominence as a natural feature, was so impressed by the size of the canyon and the enormous erosional force needed to produce it, that he sought to explain it by a single catastrophic deluge due to the sudden collapse of an immense ice-dam releasing a vast flood of impounded water. Similar sudden failure of artificial reservoir dams has been known to cause devastation of which the impounded waters flowing at normal rates would have been incapable, as in the well-known cases of the Johnstown flood in Pennsylvania and the St. Francis disaster near Los Angeles. While this catastrophic explanation for the Grand Coulee has been discarded in favour of less extreme torrents of water working over a longer period of time, there is no question as to the tremendous scale of active erosion. Forty cubic miles of basalt, even if well jointed, are not easily removed. Steamboat rock, shown in the sketch (Fig. 3), is an erosion remnant with a mesa-top nearly a square mile in area. It must have stood up as an

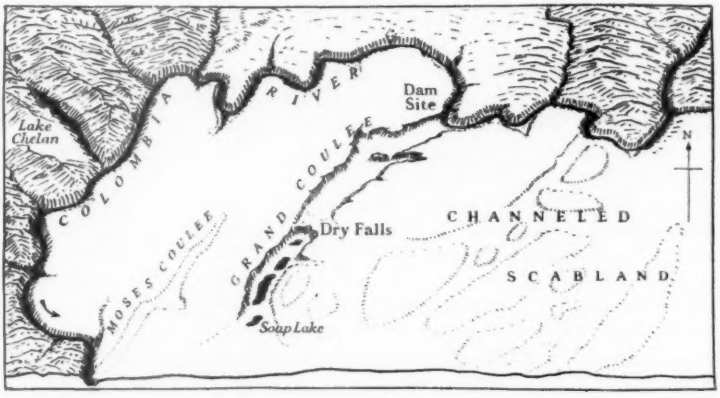


Fig. 1B

island 400 feet high splitting the flow into two streams which rejoined, flowing down the Upper Coulee for 20 miles before plunging in a cataract. Dry Falls (Fig. 4) at the head of the Lower Coulee is a horseshoe cascade, 400 feet high and a mile across: one unit of a festoon of cascades 3 miles wide, abandoned by the Columbia once the ice-dam shrank far enough for the water to rediscover its original channel.

The purpose of the Grand Coulee Project is to throw again a dam across the Columbia; not to raise its level to that of the prehistoric coulee spillway, but to gain sufficient head for a hydro-electric station. Part of this power will be used to pump water to a reservoir inside the coulee lip, from which it will flow under gravity by a canal down the coulee to the reclamation area. The balance of the power will be distributed by a high-tension network to transformers serving the entire region from Missoula to the coast.

[1] J. H. Bretz, "Channeled Scablands," *Jour. Geol.*, vol. 31 (1923), pp. 617-649.
J. H. Bretz, "Grand Coulee," *Amer. Geog. Soc.*, Special pub. 15 (1932); and see *Int. Geol. Cong. XVI Session, U.S.A.*, Guidebook 22, Washington (1932).

Opposite the coulee the river, here 800 feet broad, flows in a mile-wide trench a quarter of a mile deep (Plate 1). Eleven and a quarter million cubic yards of concrete will go into the dam, which is to be 4300 feet long at the crest, narrowing to 3000 feet in the river-bed, and spreading from 30 feet at the top to 500 feet at the base 550 feet below. This will give a working head of 350 feet to the water in a lake of 82,000 acres stretching back 151 miles to the Canadian border. The eighteen turbines in the power-house will each deliver 150,000 horse-power. Of the total power generated, 65,000 horse-power will be needed to work each of the twelve pumps for the irrigation basin. Using ten of them (each handling 1600 cubic feet a second) a total of 30,000 tons of water a minute is to be raised 280 feet from lake-level to the reservoir at the head of the coulee. At this rate of supply the daily consumption of water in London (310 million gallons) could be handled in 45 minutes, while the needs of the city of New York could be more than dealt with by pumping two hours and a half per day.

The plan of the United States Army Engineers also provides for nine other smaller dams farther downstream, so as to use 92 per cent. of the total fall of the river to sea-level. By controlling the flow of the Columbia, the Grand Coulee Dam will double the output of the subsidiary power plants above the confluence of the Snake River, and increase by 50 per cent. the efficiency of those nearer the ocean, which would otherwise lose valuable energy over the spillways during high water.

I have visited the dam site on three occasions: first as a member of the International Geological Congress Party in 1933, when nothing but surveyor's stakes and a ferry-cable marked the spot. A second visit in July 1938 found the place occupied by an army of engineers and construction crews, six thousand strong, the dam already rising above river-level, and quadruple rail-tracks on frameworks of girders carrying train-loads of concrete in endless processions from the mixing towers above the two abutments to their aerial delivery points 200 feet over the dam.

A year later I had the privilege of going over the ground with Dr. Charles P. Berkey, Consulting Geologist to the Bureau of Reclamation, and Drs. Grant Gordon and W. Irwin of the geological staff at the dam. The original population of twelve at the ferry-bank had risen to nearly sixteen thousand, the steel framework of the previous summer was buried in the heart of the dam, and concrete was being fed from a single giant mixing tower to a new trackway 200 feet above the old. Water was already rising in the lake behind the dam (Plate 1) and the twelve pumping tunnels had been driven through rock to the level of the Upper Coulee reservoir.

The structure is a gravity dam, relying on its weight of 25,000,000 tons to hold it in place against the pressure of the impounded water, without any lateral thrust against the side walls of the canyon as has Boulder Dam. The dam and power plant are to cost $200,000,000; the irrigation scheme if carried to completion will double the cost. Before the final plans were made nearly 6 miles of diamond drill holes had been bored, some a yard in diameter, so that the geologists could be lowered to examine the rock on which the structure was to rest. The river was then partially diverted by 127 miles of steel sheet piling driven into the river-bed to form the west coffer dam,

1. Air view of Columbia River, Dam, and Grand Coulee, with Steamboat Rock in background

2. *Night view of Grand Coulee Dam*

walling off the water so that the foundations could be cleared. To anchor the dam firmly on bedrock, it was first necessary to remove 18,000,000 cubic yards of overburden—clay, sand, gravel, and boulders—and a million of solid rock. For the concrete aggregate, a belt conveyer was set up to carry sand and four grades of gravel over a mile from the kame-pit to the mixing plant. Part of the conveyer is visible as a straight dark line in the left foreground of Plate 1. The cement arrives in bulk by rail in 30-ton freight cars, is sucked up into storage towers at the siding above the west abutment, and then blown a mile across the river through a 14-inch pipe under a pressure of

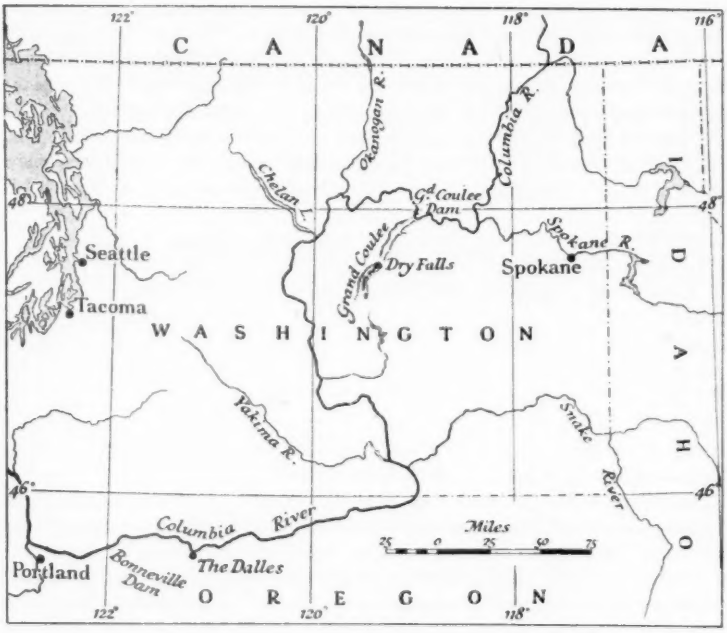


Fig. 2

110 lb. In a single day as much as sixty-three car loads of cement has been shot across to the mixing tower. Here it is mixed in hoppers for two and a half minutes with the correct quantities of gravel, sand, and water, and 4-yard charges of liquid concrete are dumped into 11-ton buckets which are filled in sixteen seconds and empty in six. The control of the mixer is entirely automatic, mere pressure on an electric button securing the delivery of any desired grade and amount of gravel or other ingredients. Self-actuating recording instruments keep continuous note of every operation. The whole process goes forward as if by clockwork. Four buckets of concrete are carried on each Diesel-engined train and at times of peak load twenty-two trains may be on the trestle at once. At one period in 1938 concrete was poured at the rate of

9300 cubic yards in twenty-four hours day and night for five months. The record day's pour was 20,680 yards.

To offset the danger of expansion due to heat evolved during setting, and of later cracking through shrinkage on cooling, the temperature of the hardening concrete is lowered 50 degrees by pumping water through 2000 miles of piping embedded in the dam. The concrete is poured in frames 50 feet square and 5 feet deep, forming blocks of a size calculated to develop contraction-joints three-sixteenths of an inch wide, which are grouted tight with liquid cement after the whole mass is thoroughly cool and hard. As an additional safeguard, there are 8 miles of galleries to give access to the heart of the dam where readings can be taken on 1500 thermometers and strain-meters embedded in the concrete, and its condition constantly watched.

When the excavations undercut the east slope so far that it started a landslide, threatening to cause a first-class disaster, the engineers built a giant refrigerating plant, thrust 6 miles of piping into the slipping mass, drove chilling solutions through the system, and froze the whole hillside solid. The temperature was kept down for seven months until the foundations were safely in place. Then the mass was thawed out by connecting the pipes with

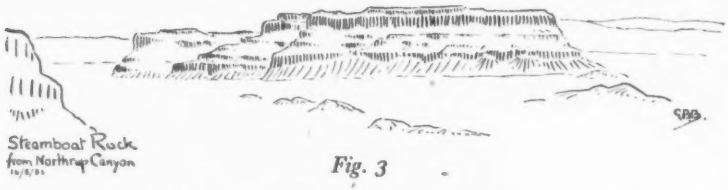


Fig. 3

the dam refrigeration system. Finally liquid cement was forced in, grouting the hillside and fixing it permanently in place.

A similar serious problem arose when the ground started to slide beneath the horseshoe bend of the roadway beside the west abutment (on the right of the air photo, Plate 1). In this case, to prevent further slumping, a vertical shaft was sunk in the unstable overburden of ancient glacial outwash, and two tunnels were driven out horizontally from the foot of the shaft towards bed rock. In three months 100 acre-feet of water drained out and were pumped up, showing that the hill slope was highly waterlogged. In August 1939 the seepage into the tunnels had shrunk from 300 gallons an hour to 90, and a third drift was shortly to complete the unwatering. Removal of this weight of water has greatly lessened the risk of further subsidence by reducing the weight of unstable sediment and drying out the clay layers which had acted as lubrication surfaces, thus stabilizing the whole hillside.

The dam is to be completed in 1942 and irrigation will commence the following year. The soil to be irrigated is mainly fertile glacial sands and silts. For full crops it should have 40 inches of rain during the growing season, whereas of the scanty annual rainfall, which seldom exceeds 8 inches, only a little more than 3 inches fall at that season. In summer the day temperatures run high and evaporation is correspondingly rapid. Thermometer readings of over 100° F. are not uncommon in the Coulee area and a maximum

of 116° has been recorded. The high-water period of the Columbia, from May to September, coincides with the farmer's greatest need for irrigation. Water will be pumped from the main river reservoir into a balancing reservoir, 27 miles long, made by throwing low dams across both ends of the Upper Coulee. This will deliver a regulated flow to the main canal which in turn will feed lateral distributaries supplying the area to be irrigated. The Bureau of Reclamation has surveyed the land and will determine the best size of farm units, probably 40 acres or less, and will control the settlement of the area, opening up sections in succession and insisting on complete settlement of each section before permitting development of the next. The soil and climate are suited to temperate-zone crops, and, with an adequate water supply, should furnish good yields of wheat and fruit besides being favourable to livestock, dairy, and general farming.

Two power-houses at the foot of the dam, each 765 feet long and 112 feet wide, will together deliver a continuous 950,000 kilowatts and have a final capacity of double that amount, thus making the plant the largest in the world, twice the size of that at Boulder Dam and equal to all the plants at Niagara combined.

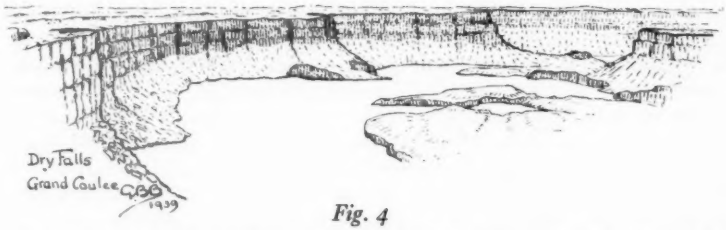


Fig. 4

Less than half the power generated will work the pumps for irrigation. The remainder, an annual output of nearly 5000 million kilowatt-hours, will be distributed over a high-tension grid covering the state of Washington and the adjoining parts of Montana, Oregon, and Idaho, supplying low-cost electricity to the port cities of Portland, Seattle, and Tacoma, and making possible new industrial developments in smaller communities. The other power plants of the Columbia River Project will be linked into the system as each is completed. Thus far only Bonneville Dam is actually in operation. The river is tidal well above Portland to a point 140 miles from its mouth, and here a dam has been built which under normal conditions raises the water-level 55 feet ("Improvement of Columbia River at Bonneville, Oregon," War Department Corps of Engineers U.S. Army, Bonneville, 1939).

The plans for Bonneville had to take into account factors not involved at Grand Coulee but which, if disregarded at the lower dam, would have led two groups of interests, the salmon fisheries and river navigation companies, to block the whole scheme. Though river traffic above Portland is not flourishing, barges do ply as far as the Dalles, 46 miles beyond Bonneville. To-day the wharfs at the Dalles are idle much of the year and the town seems to thrive mainly on overnight tourists bound for the Coulee; but in view of

the anticipated development of the hinterland with the advent of cheap electric power, no scheme would have been acceptable which permanently closed this stretch of the river to all shipping. The dam had therefore to include a lock capable of raising boats from tide-water to the upper level. At extreme low water this calls for a lift of 66 feet, the greatest of any lock yet built. Since the dam also deepens the channel up river, ocean going vessels will be able to reach the Dalles, once the channel from Bonneville to the sea has been sufficiently deepened, by a lock 500 feet long and 112 feet wide.

The fate of the salmon was hotly debated, canning factories protesting that the dam would discourage fish from running up to spawn, and would thus kill a thriving industry worth two million sterling. The controversy aroused intense feeling, so that everyone in the area became fish-conscious. To meet the protests, the plans were drafted to include both salmon ladders and fish lifts, and the U.S. Army Engineer's Office issued a special report on "Fishways at Bonneville Dam." The two fish ladders are sloping passageways 40 feet wide with cross partitions or baffles every 16 feet. The crest of each partition is a foot higher than the one next below, so that the flow of water produces a series of pools 6 feet deep separated by miniature waterfalls. The current is adjusted to an amount which induces the fish to swim rather than jump from pool to pool. Submerged holes in the partitions also allow a large number of fish to swim up without ever rising to the surface.

For fear that the ladders would not prove sufficient inducement to uneducated salmon, the dam was also provided with fish lifts, working like small navigation locks but furnished with inclined submerged grilles or gratings which rise and fall automatically. After the lower lock gates have closed and water has been admitted, the grating is hoisted to keep pace with the rising water-level. Being tilted towards the exit, the rising grille urges the fish gently but firmly to leave the lock when the upper gates open. The installation of fish locks in pairs allows one lift to be always down and open.

Those responsible for the details of the plan evidently made a special study of fish psychology; they found that the attraction of any fishway depends on a combination of magnitude of entrance and quantity of water discharged through it. Bonneville meets this demand by a new system of expansive portals, through the floor of which rises a large auxiliary supply of water fed from submerged diffusion chambers; thus ten times as much water appears to leave the fishways as actually starts down from the top of the ladders, and the fish imagine they are about to enter a fair-sized river.

Salmon run up river only once to spawn and then die; hence only young fingerlings travel downstream. Extensive laboratory and field tests have shown that small fish pass through the turbines without injury, being cushioned by the water whose speed they share. Steelhead trout and a few other species however do occasionally go back to the ocean and return to spawn a second time. To preserve these, four special by-passes have been built with entrances at the points where down-traffic fish are most apt to approach the dam, close to the shore where the water flows quietly.

Careful tally is kept of the fish running up, by placing keen-eyed observers at counting stations along the fishways. At each of these points all the fish are forced to pass through a single narrow opening in the partitions and over

a white board on the passage floor against which the outline of the fish shows up for an instant. The counters must distinguish and record each species of fish, and report the totals hourly. During the first six months actual visual count showed 363,950 salmon of four distinct varieties, 106,884 steelhead trout, and 2213 other game fish, besides 5321 shad, 3102 whitefish, 223,248 lamprey, and 376,272 counted as "scrap fish" including chubs, carp, suckers, squawfish, etc. The hourly counts, checked against the daily commercial catches at points both below and above Bonneville, show that the dam does not produce a traffic jam nor delay the arrival of waves of abundance when the fish are running up. In fact the ladders have proved so completely effective that the fish locks are seldom in operation. During the first season five salmon hatcheries above the dam obtained an aggregate of forty-two million salmon of one variety (chinook) alone: 10 per cent. above the average for these stations.

Like certain other large-scale federal experiments, the Columbia Basin Project is still on trial and its prospects of success have been challenged by economists and others. The estimated cost to the farmer of £18 per acre, and the assumed annual charges of ten shillings each for operation and for instalment on water rights, may prove optimistic. Some of the rosy pictures painted by promoters and speculators in encouraging new industrial ventures will certainly fade or develop drab patches. But the enforced abandonment of eroded and submarginal lands in the Dust Bowl and elsewhere, and the natural expansion of population are facts, and these the development of new areas may help to offset, as did the cultivation of the Imperial Valley and the Great Valley of California in the early years of the century. Moreover there is truth in the official contention that the North-western States can never be self-supporting. They are now, and will continue to be, heavy buyers of eastern agricultural products. Their own products supplement, rather than compete with, eastern crops in yielding a balanced national diet. One cannot but admire the imagination and initiative which have given birth to the whole Columbia River Project and have already done so much towards its realization since ground was first broken at Bonneville and the Grand Coulee in 1933. It will be interesting to see the progress reported at the end of the second seven years.

Note on the geology of the Grand Coulee area

The details are drawn from three sources: the published reports cited in this paper, personal observations made on the spot during three visits to the area, and information placed at the writer's disposal by the geologists of the Reclamation Bureau, especially by Dr. C. P. Berkey, Dr. Grant Gordon, and Dr. H. Irwin, to whose careful field work most of our detailed knowledge is due.

The oldest formation exposed is a white mica-free hornblende granite, which while developing two facies is apparently all related to one parent mass, the Colville batholith. This is presumed to represent the same stage of igneous activity which gave rise to the great Idaho batholith of approximately Jurassic age. Of the two facies, the older medium-grained one is jointed and therefore slightly less resistant than the broad dikes of younger fine-grained granite. The latter type is therefore more often exposed in the bottom of the Coulee erosion

trough. The granite has surprisingly few pegmatite veins, but is occasionally cut by basalt dikes several inches across.

The immediately overlying basalt lavas are interlayered with contemporary freshwater deposits of the Letaw formation containing fossil sequoia, ginko, and other plants of Middle Miocene or slightly younger age. There was therefore ample time before the mid-Tertiary volcanic outbreaks for the Mesozoic granite to be exposed by erosion and reduced to a rugged floor of some 500 feet relief. The lavas have an aggregate maximum thickness of over 1000 feet and are all of the same fine-grained type with one exception, a single coarse-felspared flow found by Dr. Irwin, which is an all-important horizon marker in checking the structure. Seen under the microscope, the rock is an olivine labradorite basalt with a very small amount of angite. The vesicular layers are often zeolitic.

Although the simple horizontal structure of the basalts is only faintly disturbed, it is thrown into one pronounced north-east–south-west monocline which passes locally into a fault-fracture with a throw of 1000 feet. This must have produced a well-defined trough at the surface. The flexure follows the line of the Grand Coulee and it was evidently the factor which determined the direction of overflow of the impounded Columbia, and thus led to the excavation of the coulee itself.

A fault with downthrow to the south-east crosses the coulee obliquely north of Coulee City and gave rise to a waterfall which worked headwards for 27 miles, developing the Upper Coulee. Similar headward erosion from the foot of the Lower Coulee was arrested by diversion of the water when the fall had receded as far as Dry Falls.

The glacial history is complicated. Along the valley walls of the Columbia are remnants of twenty-one distinct terraces which, like the parallel roads of Glen Roy, must date from the last stages of local deglaciation. The Upper Coulee shows glacial action on roches moutonnées and deposits of till which must be slightly older than the terraces, but no doubt represent the maximum of the same ice advance. They are therefore assumed to be of Wisconsin (Wurm) age. However the coulee itself was already in existence and must have been cut previously. Hence the ice advance responsible for the first great damming of the river must have been an earlier one. In view of the absence of any evidence of a third glaciation, the actual coulee-cutting is tentatively regarded as Illinoian (Riss). This interpretation tallies with Flint's conclusions for the Okanogan valley and adjacent areas.

THE BAMU–PURARI PATROL, 1936

IVAN CHAMPION

Continuation of a paper from the September Journal

October 27. We left Lake Kutubu with five guides and travelled over undulating forest country E.N.E. and N.N.E. down to the Mubi river. It was 40 yards wide and was smooth-flowing with low flat banks where we forded it. On the banks of the Mubi our guides, before leaving, showed us a track which they said went to the Wage and Augu. The track was not well defined, but we were able to follow the footprints. We travelled along the right bank of the Mubi for several miles in a N.N.W. direction over flat forest country. At 12.20 p.m. the track left the river and our direction was north and N.N.E. Shortly after, we began a long climb up a spur with trailing bamboo. We reached the top of the spur at 2.30 p.m. and made a gradual descent to a creek, where we camped.

October 28. Immediately after leaving camp we climbed to a ridge and then had a steep descent to forest flats, our direction being N.N.W. until we came to a bark shelter. Thence the track took us up a long spur to the top of another ridge with a bark shelter. There was another track branching off to the east, and through the trees we could see a wooded range in that direction. Our track now went N.N.E. and brought us to a river 25 yards in width and flowing south-east. Half an hour beyond the river we crossed a large creek which joins the river and camped on the bank. The carriers found the travelling hard.

October 29. We climbed gradually to 5000 feet, then went north-east down to a very large track coming from the west, which we followed to the E.N.E. and a few minutes later came to a log bridge. We hurried up a ridge through long sirio grass, and came into a grass sward around a village, near which a steep limestone pinnacle rose. One of the natives here called the steep valley, which could be seen below, flowing south-east, the Augu. We asked him to guide us and set off towards the river. We crossed the Augu where it ran through a deep limestone gorge which was only 10 feet wide, and climbed through limestone to enter old garden areas. At 11 a.m. we came to a house on a cleared ridge surrounded by gardens. There were several men here and we were bidden to camp as it was a long way to the Wage. They called the place Hawubi. We asked for food but they brought none. (Camp 42; 4693 feet.)

October 30. We went down the valley to the S.S.E.; it is narrow and steep, and above us the range was precipitous limestone. The population here would not be more than two hundred. At 7.25 a.m. the track swung away from the river and gradually drew round to the north-east. At 10.15 a.m. we started to climb through limestone country, with craters and sharp pinnacles. We thought we had reached the summit at 11 a.m. The carriers were all up within half an hour of me—a magnificent effort on their part. We went down into a large crater and then up again to another rim, only to crawl down into another. The guide pointed out that over the next rim was the Wage. Then he said

he would go down to the Wage with us. He led us up on a broad track through sirio grass, and an elderly man took us to a house in a circular plot of green grass surrounded by casuarina trees. A thousand feet below was the Wage river winding to the south-east. Along its banks were green gardens laid out in squares, and below us were copses of casuarina trees with little houses showing between them. To the north-west, and above the left bank of the river, the country sloped away gradually and here great columns of smoke were rising. The descent to the valley was very steep. At last we reached the flat and a dozen men awaited us. There was a small house like a dove-cote, and from a hole in it peeped a skull. We asked for a camping site and the men led us down a broad track to a little grass park surrounded by casuarina trees. (Camp 43; 6647 feet.)

October 31. We discovered that the valley to the north-east was called the Wela and we set off at 6.40 a.m., travelling down towards the river. The tracks were broad and clean and we passed many hamlets, each surrounded by a park of casuarina trees. We crossed the river by a liana suspension bridge. It was 35 yards wide at the bridge, but above and below opened out to 50 yards. It is here 5012 feet above sea-level. We climbed up the north-east side of the valley through grass country interspersed with old gardens and copses of timber, and camped on a small grass patch near a house.

We spent November 1 and 2 exchanging shells for food. Koriki told us that Hides had crossed the Wage about 5 miles above. Hides calls the valley Waga Furari, and this evening a native, pointing up and down the valley, said, "Wage Feravi."

November 3. Three men came to take us over the limestone range, and we immediately started to climb it in an E.N.E. direction. On the top we came to a depression with two houses and a garden which we were told was the boundary of the Wage and Wela people. The highest part of the track was 7300 feet above sea-level. We descended through sirio grass to a new garden in which eighteen natives were working. Accompanied by them we passed through tall sirio grass, and between steep limestone pinnacles, to a large valley about 5 miles wide. To the north-east were several hills like pyramids and beyond them a higher range. The direction of the valley was south-east. The police recognized the valley as the one Hides came down. He calls it the Wen, but this word means "presently," the equivalent to the Motu word *dohori*. We went on to the north-east on a broad track through short grass and soon came to a crowd of fifty men who had been making fence timbers. They all had stone axes. Accompanied by them we continued to the north-east over the undulating grass spurs. We passed through a wide avenue of casuarina trees to a grass lawn, where we were bidden to camp. I learned that there was another valley to the north-east called Kabu, to which they promised to guide me.

November 4. With several men as guides we went along a broad track to the north-east, passing through many casuarina parks, each with their clusters of houses, down to a shallow river about 20 yards wide flowing S.S.E., which they call the Nembia. We crossed it by a wooden bridge and climbed to some houses on a knoll. Still following the broad track we reached another park where ninety men were sitting in a line. Before them were bananas,

Dancing house, Mendi valley

Village, lower Kagole valley

Looking down Wage river

Kagole valley natives

Lake Aririvia

sugar-cane, and potatoes which they signified belonged to us. We passed over a ridge and descended into a small valley. On the steep slopes were acres and acres of gardens, neatly laid out in squares; some, owing to the steep slopes, were terraced. Another crowd of forty men met us on a knoll, but only five men came to guide us up the valley. We crossed the stream in the valley called the Enabu, and when we climbed a spur the other side we saw that the Nembia and the Enabu joined 2 miles down. As we climbed a spur we got a fine view of the whole valley, the grass mounds of the Wela stretching away to the north-west. We camped at an altitude of 7080 feet.

November 5. Three men met us on the track and led us along a spur where we had a magnificent view of the valley. They took us N.N.W. and down to the Enabu river again. At 7.30 a.m. the track turned to the north-east and we came into a grass depression sloping to the west. We arrived at another little park to find men waiting with a present of sugar-cane and sweet potatoes. The guides told us they would return, but pointed out three men who would take us into the next valley. We were led off to the north-east, gradually climbing; then we got into forest country, but the slope was very gradual. We reached the summit of the divide at 7593 feet and continued over ridges at the same level for another mile until we came out into a depression with some gardens several hundred feet below the summit. As a thunderstorm was working up we hurried down the steep track in long grass and came to a creek with some trees and pitched camp. Several men brought potatoes, and told us that a bridge crossed the river but that they were enemies of the people on the left bank.

November 6. We followed our guides down the grassy slopes to cross a creek flowing north into the Kawuku. They took us up a wooded ridge and down the other side towards the river. We went down a long spur and came to a park where men sat in a line with presents of sugar-cane and potatoes. We turned down the valley making towards the river, but shortly after leaving the hamlets we came into a wood copse where more men were sitting in a line with the usual presents of food placed in a square. They led us towards the river flats where square gardens showed bright and green, and across the river by an arched wooden bridge. It was 50 yards wide with low banks, and along the banks were graceful casuarina trees. (Camp 48; 5801 feet.)

November 7. We got away at 6.10 a.m. without guides, but a few minutes later three men joined us and I offered one a tomahawk to take us over the range. We went up grass ridges with gardens, the fences being made of cane grass because there was no wood. At 7.35 a.m. we started a steep ascent through wooded country up the range and came to a grass lookout. Owing to heavy mist we did not get a view; this was unfortunate, as the lookout commanded the whole valley to the south. The formation of the rugged range on the west side seemed to be limestone, but where we were was mudstone. The top of the range was reached at an altitude of 8186 feet and we started the descent to the next valley which our guide called Mawnd. A few minutes later we came to a lookout and to the east was a large dome mountain with tundra slopes near the top. I recognized it as Mount Giluwe. Northward were many high wooded mountains with a large grass basin on their southern slopes and stretching for miles towards Giluwe. Below was a small valley

going north to join the basin. We descended into the little valley by a very steep path and we counted twenty-five houses among casuarina trees. We went down over spurs until we came to a beautiful casuarina park with thick green grass, and here we camped. Men came in until there were about a hundred and fifty, and we were able to obtain food by barter. We decided to stay for a day as we had plenty of food which we could not carry.

November 9. Several men came to show us the track. I indicated that I wanted to cross the basin, the correct name of which is Mendi. Crossing the small stream which flows through the little valley we passed over grassy spurs with houses dotted about and many gardens. Travelling to the north-east we recrossed the same stream which is called Kaia. Adamson prospected it but could find no colours, though he believed we were in country which is likely to be gold-bearing. From a knoll we had a fine view of the valley stretching for miles to the S.S.E. It seemed to be well populated. Another stream was crossed which is known as Wabu, and the guide said the district was called Ivuale. A broad track, cut out of the hillside and with wooden steps, brought us to a park through which we went to come out on a cleared piece of flat land on which were three long houses 96 yards in length. Two hundred men and boys sat in rows before them. Apparently these houses are for guests who have come to dance. Behind the open space was a fine casuarina park overlooking a river which they told us was the Mendi. We went down steeply and crossed it by a wooden bridge. Camp was pitched in a casuarina park on a ridge. We bought food here with red calico and cowrie shells. We saw many steel tomahawks, but they were old and blunt; the farther we went east the better were the stone tomahawks. We could see the Mendi basin narrowing 6 miles to the south, and all the way down were gardens and habitations. It was the most populated valley we had yet seen and I estimated the population at about six thousand natives. We were now on the eastern side of the Mendi basin, and the western slopes of Mount Giluwe. My original route was between this mountain and Mount Ialibu, but the long flat basin on the north-western side of Mount Giluwe attracted me, so I decided to go north of the mountain. (Camp 50; 6470 feet.)

November 10. Went down to a flat where two men met us and took us over gullies in a northerly direction for fifty minutes, and then up a spur to reach a park and houses. We followed a broad track through wooded country gradually climbing for an hour to the east and then travelled along a muddy plateau with trailing bamboo. At 9.30 a.m. three men met us, armed with bows and arrows, and consented to guide us to Pivia. Shortly after the plateau dropped away, and below us, 200 feet down, was a beautiful lake, about 200 yards wide and 400 yards long. The men called it Aririvia. It was bordered by scrub, and over the scrub were flat ridges covered in grass with much smoke rising. Beyond that rose the gentle slopes of Mount Giluwe, first wooded, then with the tundra formation; the summit was a high crag like the crest of a cockatoo. The natives pointed to it and said, "Kari Giluwe." We went down near the northern side of the lake and saw ducks on it; then we came to the edge of the scrub and looked over grassy ridges towards a very flat basin extending for 2 miles to the east and north. On the east end were the gradual wooded slopes of Giluwe, and on the northern side

it rose in a terrace of grass ridges which merged with scrub from a high range flanking the northern end of the Mendi basin. More men met us here and we descended on a broad track to a grass park. We saw that the large flat basin was a marsh, though there was a track over it; on the south-eastern side were villages and gardens, and I decided to go that way instead of across the basin. A man took us on a track which skirted the basin. We could see gardens on the wooded slopes of Giluwe; the open grass had a peculiar dead look like that of the Wela. It seemed that it was unproductive and the natives were going farther up the mountain to make gardens on new soil. At 1 p.m. we came to another village where there were thirty men, and continued to a large garden on the wooded slopes of the mountain. I was soon doing a brisk trade with red calico and small cowrie shell for sweet potatoes. The men have curious little curved smoking pipes not much thicker than a European cigarette-holder. They asked us where we were going and I pointed to the direction of the Kagole, and one man suggested that we went over Mount Giluwe to the E.S.E. There was a cold wind blowing but the night was bright with stars. I got observations, but unfortunately the wireless set had not been able to get signals for some days, so that we had to take the average rate of the watches. I think there is some local interference. (Camp 51; 6° 01′ 42″ S., 143° 45′ 33″ E.)

November 11. Guides led us down towards the depression until we struck the main track near a group of villages. We travelled round the edge of the basin in a north-easterly direction over grassy spurs and crossed many small creeks. We reached a casuarina grove on the banks of a large creek flowing west into the depression. Our guide told us the villages were called Romia, that the track went east from here to the Kagole, and he gave the names of several districts: Kurimindi, Tarari, and Puguwe. Travelling east through grass country we passed many little parks with houses scattered round them. The tribes to the north fight these people and they showed us a large track leading in that direction. Over Giluwe was a lake called Buna, and a prominent mountain on the range to the north was Ramindi. At 10 a.m. we came to the edge of the grass country. Our guide told us to follow the track which would take us to Kurimindi and Tarari, and he added Purua, Wabia, and Ingia. We climbed through wooded country, the track leading up to a wooded spur of Mount Giluwe which joined the ranges to the north. The track got steeper and there was a dense undergrowth with much trailing bamboo. Much to my surprise we came out on the tundra formation below the high peaks of Giluwe. This grass stretched in a long curve, like the bed of a river, and on each side was a belt of beautiful pine trees. The slopes of the main peaks rose gently before us. To the north were high tundra-covered mountains contiguous with Mount Hagen. The track was broad and much used and we found a camp site in a gully at the edge of the pine forest. (Camp 52; 9270 feet.)

November 12. We crossed a small tundra plateau going east, and passed an old shelter into forest country, the track going south of east. There was a gradual climb. At 7 a.m. a large creek was crossed and at 8.10 a.m. we came out on a spur of moss and fern. After crossing a patch of scrub we went up the sides of a grass ravine, still gaining altitude. It looked as if the track

would take us over the summit of the mountain, but after crossing the creek in the ravine it went up the other bank of the ravine to the E.N.E. From the top we had a remarkable view of the great mountains stretching for 70 miles or more. Below (north-west) was the bright green of the Pivia and Mendi basins with their streams showing like streaks of silver. To the south—3 miles away—was the rocky central crag, the summit of this huge mountain. Far to the north-west rose a sharp peak. Our altitude was 11,640 feet. We got away at 11.25 a.m. following the well-defined track to the east over a vast plateau and, descending into a basin with many ponds, climbed to the top of another ridge at a height of 12,000 feet. A long ravine went down to the east and I could see the grass valley of the Kagole with the peaks of the Kubor range beyond on the Wahgi valley. A cold wind was blowing up the ravine and heavy clouds were coming up, so we made for a patch of scrub about a mile away down the ravine. Here we found a shelter of bark, but we went on a little farther and erected camp (No. 53; 11,480 feet) at the edge of the stunted scrub. The strong wind died down at dusk and the stars shone brilliantly.

November 13. The temperature was 30° F. at 5 a.m. I sent the men back to wait for the sun to rise. At 7 a.m. the temperature was 32° F. We broke camp at 7.30 a.m. to continue down the ravine. We turned into some scrub and came out on a grass patch where we saw the Kagole valley beneath. The river was winding through green flats and the valley was about 5 miles wide. Mount Hagen was to the N.N.E., and away to the east were the high peaks of the Bismarck range with the Kubor mountains nearer to the E.S.E. The Wahgi valley was covered in clouds. We descended into mossy forest country in an E.N.E. direction, and then entered more open forest with much pandanus. At 11.20 a.m. we dropped into a large creek and cooked some rice. While we were sitting here three young men approached us and took us along the track into grass country which sloped gradually towards the river to a grass path with some casuarina trees and four houses. (Camp 54; 7307 feet.) These people have seen Europeans, for the Leahy brothers have been in this valley and to the summit of Mount Giluwe. The Leahys call the valley Gauil or Kaugel, but the pronunciation seemed to us to be Kagole. We could see the head of the valley to the north-west where it opens out in a basin just over the border; one stream comes from Mount Hagen and another from the northern slopes of Mount Giluwe. Mount Hagen bore 8 degrees magnetic.

November 14. We took a large track down the valley. The Kagole river is about 2 miles away. We picked up a guide a few minutes after starting and travelled fast over a broad track and on undulating grass country. The guide told us that our camping place was Tarari, and at 7 a.m. we passed through the Kurimindi hamlets. Later we entered wooded country which was steeper and then found ourselves above the Kagole river where it flows in a gorge. We soon came into grass country again and were told it was the Wabia district. Wabia men accompanied us and pointed out the Tembabu villages on the left bank of the Kagole. We went on to meet thirty more men of the Agebangi district and came to several houses in the Poriba district. We camped ½ mile on in a little park called Polebu. (Camp 55; 6686 feet.)

November 15. Our track down the valley ran south-east, but this morning we turned more to the south heading for Mount Ialibu. Giluwe was now bear-

Tive plateau man

Shrine on Poru plateau

Suspension bridge, Wage river

Karimui communal house

House in Wage valley

ing west. A long spur ran south from Giluwe to a plateau between that mountain and Ialibu. There were patches of scrub and grass as far as the eye could see and the smoke of many fires. We crossed a large creek flowing east and came to a village; then down a long flat grass spur to the south-east to a cluster of houses among many large gardens. A youth guided us over a steep spur and across a deep creek spanned by a wooden bridge. We turned up a track to the south-west towards a wooded spur on the north-east slopes of Mount Ialibu. We reached a casuarina park at noon and made camp (No. 56; 5° 06′ 08″ S., 144° 06′ 54″ E.). I was able to get observations and time signals.

November 16. Mount Giluwe bears 287 degrees magnetic. We can look up another valley, called the Nabilie, between the Kagole and the Wahgi. The Kagole meets the waters of the Nabilie 3 miles north-east from our camp and then flows east. We are 2 miles from the border, and our route down the Kagole has been parallel with the border. (Resting at Camp 56.)

November 17. Went on to the east and south-east. We were soon enveloped in thick mist and we passed over grassy spurs without any habitations until we reached the Ikomele hamlets on the left bank of that stream. Men brought us sugar-cane and led us on down a grass spur to the east along the left bank of the river. The mist cleared and we saw before us long grass flats with copses of timber extending down to the Kagole. On the other bank of the Ikomele are high wooded spurs on which there are many gardens though the population is small. At 10.10 a.m. we stopped at a house and decided to camp (No. 57; 4627 feet). The grass valley ends a few miles down, and to the east and south-east are wooded ranges going towards the Purari.

November 18. Went down the grass flat for forty minutes. We saw Mount Giluwe for the last time and then crossed the Ikomele river by a wooden bridge where the river runs through a gorge 10 yards wide. Travelling through forest country, over gullies, we reached a garden and three houses. A steep descent brought us to a large creek flowing to the north-east and we climbed out of this to continue through forest country. On the banks of a creek we found a large garden with sweet potatoes and sugar-cane. Crossing this we found the track had turned to the S.S.W. A broad track took us through a new garden and up a spur into a large village of thirteen houses. The houses were similar to those of the grass lands, but they were larger and thatched with grass. Men and women were very friendly and we obtained food. There was a glorious view from the village, far up the Kagole; Mount Hagen and the Nabilie valley were to the north-west, and to the north-east were the Kubor mountains, their steep spurs running down to the Kagole river which was flowing in a gorge. (Camp 58; 4266 feet.)

November 19. With guides descended to the south-east to the junction of two small rivers, the Imele and Nabene. We traversed undulating forest country until we dropped down to a large stream called the Agiba at an altitude of 3097 feet, beyond which the guides refused to come. We crossed the river and picked up the track on the other side and travelled over hilly country which changed to forest flats. The track then went south to a river 50 yards wide, flowing east. We made camp on the right bank. (No. 59; 3617 feet.)

November 20. The track up a ridge was very faint and there was much trailing bamboo. We got into a creek flowing south which was very steep at first. We lost the track, but picked it up an hour later going S.S.W. We passed an old clearing where the track became well defined, and a long climb up a spur brought us to the top of a range running south-east from Mount Ialibu. One track went to the south-east and another to the south-west. Maniti climbed a tree and saw gardens 2 miles away to the south-west, and we followed the track to a village near which we camped on a ridge. We asked the natives for food and they brought little bundles of potatoes for which they wanted axes. We managed to buy a few pounds with calico and shell.

November 21. We obtained half a ton of potatoes in exchange for seven large knives and five plane irons. The name of the village is Poru and there is a tribe to the W.S.W. called Avonda, who are their enemies. To the south-west are the Porogo, Keravari, and Kabaroi tribes. A river on the western side of the village, flowing E.S.E., is called the Po. There is another tribe called Pomba towards Mount Ialibu which we can see about 12 miles to the W.N.W. The mountain consists of three peaks in the form of a saddle with the highest peak on the east. (Camp 60; 4435 feet, until Nov. 24.)

November 24. Four men led us on a track to the E.S.E. through wooded country and across many creeks until we reached the village of Ruge. We turned to the east over undulating grass lands and then climbed a grass spur overlooking large gardens in the gullies below. We were now making for the range and we got a view from the north-west to the south. The country appeared to be a plateau extending from Mount Ialibu far to the south and west. It was intersected by many small streams and was composed of grass lands and patches of timber. About 12 miles to the S.S.W. was a limestone range running to the south-east. Later our guides disappeared. We followed the faint track to the east and north-east to the top of the range at 6000 feet. Travelling slowly N.N.E., cutting through thick undergrowth and descending, we had doubts about it being a track, and at noon decided to return. We were able to get a view from the top of the range as the clouds had lifted. To the east, 15–20 miles away, was a wooded valley coming from the N.N.E., and between us and the valley the country was very broken and there was no sign of population. At 3.30 p.m. we reached the ridge above the gardens, through which we had passed in the morning, and camped (No. 61; 4500 feet).

November 25. Three men came up, one of them being the guide who was with us yesterday. They explained that we had taken the wrong track and that they would show us the right one. They led us to their village, Wendawavi, on a ridge about a mile away. The plateau dips slightly to the south and is cut by deep creeks. I have called it the Poru plateau. Our guides told us that they would take us to the E.S.E. in the morning and said that Tirivari, Kamboro, Rauwe, and Tauie lay in that direction. (Camp 62; 4481 feet.)

November 26. We induced five to lead us to Kamboro. We went up a spur to the range and entered wooded country. Travelling E.S.E., on the top of the range on a well-used track, we came to a branch track going to the east. The guides told us it went to Tirivari. We went east by south crossing many small creeks and then turned more to the north-west. We had an almost vertical descent down to the head of a creek called Karairo. We went down

it for some distance, then left it, and came to a ground-floor house in an old garden (Camp 63; 3719 feet). We discovered that Kamboro is the name of a small dome mountain opposite us and this garden is Rauwe.

November 27. We picked up a track going to the south-east but it was very faint, and at 10 a.m. we got into limestone country where it ended. It was only a hunting track, so we went back and Adamson discovered a small garden ½ mile from our camp of last night. I decided to camp and make an examination of the country.

November 28. I was able to get some star sights just before dawn. Adamson followed another small track leading to the Karairo, but it proved to be only another hunting pad. (Camp 64; 6° 21′ 10″ S., 144° 19′ 8″ E., 3700 feet.)

November 29. We took the route Adamson had taken yesterday, and after getting on the river flats travelled fast downstream on long shingle beaches or waded in the water. The creeks coming on from the south carried limestone pebbles. At 11 a.m. the river height was 1947 feet above sea-level. By 2 p.m. the river was large, and steep spurs ran down to it on both sides. Half an hour later we came to a gorge and had to camp. I sent Koriki and Katue to see if it was possible to get round the gorge. They got back at dusk with the heartening news that we could advance as the gorge was not of great extent. (Camp 65; 7866 feet.)

November 30. River in flood. We were able with difficulty to get on to the river and cross to the left bank where there was a long shingle beach. Cutting through dense forest, in low-lying country, we came to a larger river flowing into the Karairo from the north. Fortunately the current was slow for 100 yards above the junction, and rafts were made on which we crossed. But we were not able to follow the river for long. A mile farther it turned sharply to the south—it was now a big stream—and on both sides steep precipitous spurs dropped almost vertically to the water's edge. We had to ascend one of these, and at 3 p.m. we got a view from east to south. Eastward was the plateau we had seen from the range above the Poru plateau; it sloped gently to a valley coming from the east. The Karairo could be seen flowing south for some miles and then appeared to take a sharp turn to the south-east, where another river joined it from the west. The ranges to the south were steep and rugged, and appeared to be of limestone formation. We followed the spur up to the north-east and then dropped into a saddle where we found water, and camped. (Camp 66; 2192 feet.)

December 1. Climbed a steep knoll to the E.N.E., and half an hour later we descended to a small creek flowing north and north-east, which we followed. The creek swung to the east and gradually flattened, so that we were soon travelling fast, our hopes rising because there were evidences of natives. Two large creeks joined ours from the north, so that it became large and had now turned to the south. But at 9 a.m. it turned south-west and was so large that we could not wade in it. We cut to the east through dense bush, and forty minutes later picked up a faint hunting pad. Shortly after a sago patch was found. We pitched Camp 67 and started to make sago. Only 130 lb. of rice remained, and our objective on the Purari was 40 miles away. Koriki went down to a large river, which he said was the upper Purari.

December 2. Adamson went down to the river to see if there was a crossing. The river, over 100 yards wide, was flowing west and was in flood. But when he got there Koriki told him that he knew where he was. The river was Pio, or Purari, and Koriki said that if we went upstream to the east for six or seven days we could cross it and reach the villages of Wehanua. From Wehanua we should travel for five days to the lower Purari, where we could get canoes. (Camp 67; 6° 24′ S., 144° 29′ E.)

December 3. The river had fallen, but was still 100 yards wide and flowing fast. We cut along the banks, which were steep, to a small creek flowing from the north-east. We went up it to find a track leading up the spurs, but it turned to the north-west, and we cut to the east over very difficult country until another small track was found at 10.28 a.m. Half an hour later we arrived on the saddle of a spur and got a good view to the east. In that direction was a valley, which Koriki said was the Pio, and about 10 miles to the E.N.E. was a plateau. Twenty miles to the E.S.E. was a conspicuous mountain with several peaks rising to about 8000 feet. Koriki said that Wehanua was in that direction. We followed the track round the ridge towards a garden which could be seen on the slopes of a spur. Here we were told that another river, called the Wili, was below. Several men led us down to another large garden, where we camped. Northward was a high mountain which we had seen from the Kagole. It has long sloping spurs towards the plateau and the Wili river, which comes from the north.

December 4. We got two men to take us down to the river. The track was a mere pad, and great was our astonishment, and disappointment, when we found the Wili to be nearly 100 yards wide and no bridge. We turned upstream, cutting a track over steep gullies and spurs to a stretch of the river which we thought could be crossed with a canoe. A camp site (No. 69) was selected and a duduye tree felled from which to make a canoe. It was finished at 4 p.m. next day, and in two hours the whole party had crossed. The Wili is the Kagole, and we were about 300 yards above its junction with the river from the east, which Koriki said was the Pio.

December 6. We spent the day hacking a track to the east. The country was of schist formation and was broken into precipitous creeks. Often we had to retrace our steps, and at 11.40 a.m. we pitched camp (No. 71) in a gully.

December 7. We travelled south for an hour down the creek and crossed a larger one to climb a steep spur, and continued cutting across gullies to the east. At 10 a.m. we arrived at the edge of a steep valley with a large creek flowing south. We got down to the river, and here a native track was found and patches of sago. Half an hour later we reached an old shelter close to large sago palms. We made camp (No. 72), as we had only sufficient food for one day. The next day we spent making sago.

December 9. Climbed out of the little valley on a native track which led us across a plateau. At 8 a.m. we came to the edge of another valley, or depression; one track went south-east along the edge, and another towards its head. We chose the south-east track, but had only gone 100 yards when yelling broke out in the rear from a crowd of armed men. They told us that we were on the wrong track, and that we should follow them. One of the men could speak to Koriki in his own language. This man, whose name was Bogai, lived

across the Tu river, the one Koriki had mistaken for the Pio, and the people there speak the same dialect as Koriki, who lives on the middle Purari. In an hour we reached two houses in a large garden. The men were taller than those of the grass lands, but wore the usual sporran and leaves. Their arrows were carved. The village is called Unaro, and the district is Tive; the high mountain to the north is Suauru. We learned that the Pio was still six days' journey to the south. We were just over the border in the Mandated Territory.

December 10. With an escort of thirty armed men we went down steeply to a large creek called Serisa and climbed a spur to flat forest country, after which we again descended to the Sanesa creek flowing to the south. Our direction had been E.N.E., but after climbing from the Sanesa we turned to the south-east on the plateau again and arrived at the village of Havi. Though it was only 11 a.m. I camped, as Bogai said we would have a long day to get to the Tu river and there were no villages on it. (Camp 74; 2923 feet.)

December 11. Bogai showed us the track coming from the Kagole valley, which goes north of Mount Suauru. We passed through gardens with many tracks leading in all directions, and at 8 a.m. arrived at another village. As one of the prisoners had a bad foot I decided to camp.

December 12. Led by Bogai and four men we passed through old garden lands and began the descent to the Tu. The soil of this Tive plateau was remarkably rich and was the best agricultural land we had seen. After travelling 3 miles the country got very rough and we clambered down deep creeks. The Tu river was reached at 12.30 p.m.; it was flowing west and had a width of 80 yards. Messrs. Leahy and Dwyer came down the Tu in 1930, and Bogai said he remembered two white men with a large dog who came down the river from the east. We went up the right bank of the river, clambering over spurs, and reached a cane suspension bridge at 2 p.m. The river had narrowed to 60 yards. Camp 76 was made near a sago patch 40 feet above the river (1707 feet).

December 13. A long climb up a spur brought us to a village. We travelled to the south over flat country covered in secondary scrub, breadfruit, and pandanus. In half an hour we arrived at a village called Soboro. Accompanied by many natives we travelled across this wooded plateau to the E.S.E. It was intersected by many creeks with steep banks, flowing in a northerly direction towards the Tu river. The mountain peaks seen from the Wili river are about 5 miles to the S.S.W., forming a massif, which the natives call Karimui, rising from the plateau. I have called this plateau after the mountain. We were still in the Mandated Territory; a mile over the border and travelling parallel with it. The Tu river is the lower Wahgi.

December 14. We continued our journey across the plateau to the S.S.E. At 8 a.m. we reached the village (one house) of Kei-Iaro amidst gardens, and saw a range to the E.S.E. which the natives call Moaru. Beyond it lies the Pio river. At 10.30 a.m. we reached the village of Mariara among extensive gardens, and Bogai told us to camp as there were no more villages. The next day we were to cross a spur of Karimui and reach the Pio watershed. We were back over the border again in Papua.

December 15. We struck off to the S.S.W., and after crossing Gibusina

creek climbed a wooded spur. We then travelled S.S.E. through marshy and mossy country and descended to a creek which we waded down or scrambled over for an hour and a half. We went down into more creeks; these natives use the creeks for tracks, possibly because the country is so rough. At 1 p.m. we looked over a gorge, and as our guides told us that it was very difficult travelling down there, we decided to camp. (No. 79; 3669 feet.)

December 16. The morning dawned fine and to the south-east could be seen steep limestone ranges bordering the Purari river. We clambered down into a large creek several hundred feet below, which the guides called Ivi, and soon we were twisting and turning through limestone. Above, the walls rose sheer for hundreds of feet. At 9 a.m. we got out of the creek and rested under a limestone cliff, and then went over a ridge to the south-west to turn south again, and wade down numerous creeks. At noon we arrived on a flat on the banks of a stream where there were some sago palms and three large shelters. Three men were in the shelters, and Koriki told us that these were their villages. The Pio was still another day away. We camped and asked for food, but it was not until dusk that a few more men arrived with some. The people seem to be nomads.

December 17. After the heavy rain the creeks were in flood, and we crossed Ui creek. The Ui is joined by the Hamu and below the junction the river was large. We then left it flowing S.S.W. and went up another small creek to the E.N.E. to follow a ridge to the south-east. At 11.30 a.m. we descended to flat country which the guides said was the Pio valley. To the south could be seen a limestone range, and over it is the main Purari. Wehanua is miles to the east, up the Pio. Koriki went down to the river to get information from a man who knows the track across the range. He came back and said that there was a canoe which was used for crossing the river, and that it would be brought up to-morrow to meet us. (Camp 81; 1371 feet.)

December 18. We went south to the Pio through flat forest. The river was in flood, and when we came to a narrow part 60 yards wide, which the guides told us was the crossing, there was no canoe. So we started down-river, cutting along steep banks. It ran south-west and west and was about 70 yards wide. In an hour we reached a big rubble beach and were met by natives with a canoe. The canoe was about 20 feet long, and was the only one available. The party crossed the river in seventy minutes. Koriki suggested that he should go ahead with one of the Pio men, who knew the track across the range, to the Purari, to fetch canoes. We would be some days getting there, as we had to make sago. (Camp 82; 1026 feet.)

December 19. Koriki and Kosipi left at daylight with the guide. They hoped to reach the Purari in one day. We followed the guides to the south-east over rough ridgy country to Kui creek, which flows into the Pio just above the canoe crossing. There were some limestone pebbles in it, and sandstone. After crossing the creek we went south up its right bank, and in half an hour found a sign left by Koriki, where we were to camp and make sago.

December 20. Camp 83 (6° 45′ 43″ S., 144° 50′ 09″ E.). We are 8 miles north of the Purari. The natives call the Purari Pio, and say the Pio we have just crossed takes a bend some miles to the west and then flows south-

east. Faithorn speaks of the Erave (Erewa) as the Pio, and only mentions one large stream, the Iaro, coming into the Pio. He does not say if the name is a local one, but that the Iaro is almost as big as the Erave or Pio. I was very confused at first about these rivers, the confusion being caused by the name Pio. Leahy and Dwyer followed the Tu down and saw the Pio from the east join it, but they do not mention the Erave coming from the west. We saw the Wili join the Tu, and later, the Karairo. Farther down this stream is joined by the Pio, and together they form the Iaro, which joins the Erave. Below this junction the river is known as the Pio.

December 21. Climbed a gradual ridge for forty minutes travelling south, then turned west down a big creek full of limestone and sandstone boulders; it was the Kui, and after going half a mile the guides turned off to the south up a small smooth-flowing creek, by which we camped.

December 22. We began to climb the creek through rough limestone, in places almost vertical. At 7.14 a.m. the limestone ended, the formation being slate. Still going up the creek, which was now smooth-flowing, we reached the summit of the range and went down into another creek flowing south. Half an hour later it opened out in flat country. It was easy travelling down the creek, and at 11 a.m. we came into limestone country again. The bed of the river was flat, but high limestone cliffs rose on either side. The guides call the river the Po or Poru; Faithorn mentions a river joining the Pio above the Masuwer gorge called Po. We later left the river flowing to the south-west and clambered up a dry limestone creek to the south. The track gradually swung to the E.S.E. and led us to a small clearing with a house. A native told us that Koriki had camped here.

December 23. Climbed to the top of the divide in twenty minutes. We kept going down in a series of steep descents, mostly down creeks. At 7.45 a.m. we had to clamber down a precipitous dry limestone gorge, then into another creek which gradually grew larger and the water went underground. But the travelling was now easy, for it was flat, and at 10 a.m. we came on to the banks of a large river flowing east. It was the Purari. We had reached the spot where I had aimed for, about 6 miles below the Masuwer or Hathor gorge; but my observations placed it 6 miles east of the position shown on the map. The next day we spent making sago.

December 25. At dusk a shot was heard down-river, and half an hour later several canoes came up. Much to our surprise the canoes, in addition to Koriki and Kosipi, contained police of the Kikori detachment. Koriki had met them at Gleeson island.

December 26. I was unable to get star sights here, but good solar sights were obtained. My latitude differed from MacGregor by $\frac{3}{4}$ mile, but his longitude, determined by river traverse, is nearly 7 miles too far west. The wireless set was working much better since we came into the low, moist climate. (Camp 86; 6° 52′ 50″ S., 144° 53′ 20″ E.)

December 28. We got away at 7.30 a.m. in seven large canoes. The river was running at 9 miles per hour, and we arrived at Woimadi on McDowell island (Koriki's village) at 2.30 p.m. The following day we met the launch *Palma* which was coming up for us. We arrived at Port Romilly in the afternoon, and on 3 January 1937 reached Port Moresby on the *Vailala*.

There appears to be a general belief that these grass valleys are rich agricultural areas peopled by thousands of natives. This is quite wrong. The density of the population is no greater than that of the Kambisi and Goilala districts of the Central division; but there are many more natives because they are spread over a far larger area. I endeavoured to form an estimate of the tribes through which we passed. Looking down on any of the valleys from a height one gets the impression that there is a far larger population than actually exists. The manner in which these natives live, in scattered houses, surrounded by little gardens, all tend to give this impression. I estimate the population at 25,000.

The soil is poor and the methods of agriculture are different from the ordinary Papuan, and approach the European style. Gardens are laid out in squares, and potatoes, the staple diet, are planted in straight rows of raised, circular beds to prevent erosion. The natives have had to cultivate every acre, so that the grass valleys are denuded of timber except for the copses of casuarina trees planted by the natives. Even the little pockets of earth, far up on the limestone ranges, are cultivated. I got the impression that hard work was necessary to get sufficient food for their needs. Their manner of living indicates that there is little warfare.

If the country is to be brought under Government control, I suggest that, at the beginning, lake Kutubu would be the best position for the main camp. A seaplane can land on the lake; it would be impossible to maintain a camp except by aerial transport. I saw no natural landing grounds in the grass valleys, and only by a great deal of labour could any be made. Lake Kutubu has several advantages over the grass lands: a good climate, plenty of timber and garden ground, and friendly natives, so that a large police force would not be necessary at the main camp. Should communication be cut off by air, there is a probable route to Kikori by way of the Mubi river.

Note on the Map

As explained in the Introductory Note on p. 190 *of the September* Journal, *in the sketch-map there published we adjusted Mr. Champion's work in two points: the junction of the Kagole–Nabilie and the position of Mount Ialibu, to agree with his diary. With this concluding part of his paper we publish his map as received, except that we have indicated the adjustments in those two places which we think it requires.*

Note by the Editor

As a result of the journey above described a Government Station was established at Lake Kutubu, as headquarters of a new district in charge of Mr. Champion. Writing thence on 10 December 1938 to acknowledge the receipt of the Gill Memorial, which had been awarded him in 1938, Mr. Champion added "We are just completing the transport by air of the stores for the next year's operations. This time our personnel has been increased by three European patrol officers, and for six months we have Mr. F. E. Williams, the Government Anthropologist. During the year we have made

a number of patrols north-west, north, and east from our base at Lake Kutubu. By the end of next year I hope to send you a very complete map of that area from latitude 7° to the mandated territory border, and from the Strickland river to longitude 144°. We have kept friendly relations with the natives throughout, and have not fired a shot. Five natives have enlisted in our police force for a year so that when they return to their villages they will have some knowledge of our ways. I hope to enlist at least one man from every tribe throughout this area."

PAST SEA-LEVELS AT DUNGENESS

W. V. LEWIS AND W. G. V. BALCHIN

Meeting of the Society, 11 March 1940

THERE can be few sections of coast-line which exhibit such a sequence of storm beaches as Dungeness Foreland, some of whose ancient shore-lines are also dated by historical events. The series covers over four thousand years and the first well-developed shore-line probably dates from late Neolithic times.[1] Drew [2] as early as 1864, recorded that the level of the older ridges was approximately 6 feet below that of the modern shore ridges, though he considered the difference attributable to a change in the tidal range and not to any alteration of the relative level of land and sea; Dowker [3] however considered that a change in the relative level of land and sea was responsible. This possibility at once suggests the value of an accurate determination of ridge heights, and in 1931 one of the authors (W. V. Lewis), with the help of Mr. D. F. Munsey, carried out the greater part of the levelling described in this paper. Mr. Munsey also helped with the subsequent calculations, and only his absence in the Sudan prevented his being included as a co-author of this paper. The only existing map of the ridges is that prepared by Drew for the first Geological Survey Memoir of the area.[4] Drew however was working on an Ordnance Survey map of 1 inch to the mile, and so he could not attempt the ambitious task of representing each ridge. Instead he indicates trend lines only, drawing 10 to 15 per mile, whereas the actual ridges number 60 to 100 or more to the mile. In addition to levelling, we therefore intended to map each ridge along the routes followed. To do this a composite form of traverse was made in which compass bearings and subtense distances were taken along the course, together with the bearing of each ridge crossed.

The publication o fthe results was delayed so that further subsidiary lines could be levelled. Before this programme was completed the whole scope of the work was greatly enlarged, thanks to the foresight and initiative of the late Lieut.-Col. T. T. Behrens, R.E., who, after some years in retirement, had been appointed Garrison Engineer at Shorncliffe. In the course of his duties at Hythe and Dungeness he seized every opportunity to secure information of scientific value, and he was spurred on by the knowledge that the rapid growth of building estates on the shingle flats between Dungeness and Littlestone-on-Sea would shortly preclude any further work in these areas. Amongst the many activities upon which Colonel Behrens embarked some levelling was carried out and, most important of all, with his cooperation a photographic survey of the shingle area on a scale of 4 inches to the mile was planned and later largely completed by officers of the R.A.F. station at Shorncliffe. When subsequently Colonel Behrens learned that we had already done a considerable amount of levelling and were interested also in mapping the ridges, he at

[1] Gilbert, C. J., "The evolution of Romney Marsh," *Archaeol. Cant.* 45 (1933) 261.

[2] Drew, F., "Geology of the country between Folkestone and Rye," *Mem. geol. Surv. U.K.*, p. 18.

[3] Dowker, G., "On Romney Marsh," *Proc. geol. Ass. Lond.* 15 (1897) 220.

[4] *Mem. geol. Surv. U.K.*, Old Series, One Inch, Sheet 4.

once made all his information available to us, and very kindly planned a programme of further levelling and air photography so as to fit into our scheme. Unfortunately his death cut short this work. The detailed mapping of the ridges from the air photographs must, in addition, be deferred until after the war. The levelling alone therefore forms the subject of the present paper, and the map (Fig. 1) has been produced by one of the authors (W. G. V. Balchin) from the 1-inch Geological Survey map and an earlier R.A.F. mosaic which Mr. A. R. Hinks kindly secured for inclusion in an earlier paper in this *Journal*.[1]

Results of the levelling

It was hoped that the levelling would be sufficiently accurate to show any gradual rise or fall in the height of the ridges over distances of several miles. A precise level, borrowed by kind permission of Professor Debenham from the Department of Geography, Cambridge, was used. Readings were taken on three stadia hairs both to provide a check and to give subtense distances; main staff positions were 160–180 yards apart, and as many ridge heights as possible were observed as intermediate stations. Along most of the south shore a flood wall was used for the main stations, but whenever the staff was placed on the shingle, a board, $12 \times 6 \times 1$ inches, was pressed into the pebbles until the upper surface was level with the surrounding shingle, and the staff placed on the board. As most of the ridges were intermediate stations, and so distances from the level did not matter, we were able to select positions where the shingle appeared least disturbed. The closing error in the run from the bench mark at Jury's Gut Coastguard Station to the bench mark at Galloways Coastguard Station, a distance of 3^{1}_{2} miles, amounted to $-0{\cdot}13$ feet. Parts of this line were double levelled and the closing errors on the two circuits only amounted to $-0{\cdot}09$ feet and $-0{\cdot}04$ feet respectively. These were considered too small to require adjustment, and are consistent in sign and amount with the total error given above. Our error between the two bench marks a few hundred yards apart at Galloways Coastguard Station amounted to 0·01 feet, and from the second of these two bench marks to the one at the Hope and Anchor Inn, a distance of 1^{1}_{2} miles, was 0·17 feet. The run of 5 miles, almost all on shingle, from the Hope and Anchor Inn, *via* Dungeness and the Pilot Inn, to the Pumping House bench mark near Denge Marsh Farm, gave an error of only 0·07 feet; a check by means of a short branch traverse to the lighthouse bench mark gave an error of 0·02, again consistent with the total error for this run. It thus seems that the great majority of measurements of height are correct to within an inch, and all to within 2 inches.

The advisability of taking the heights of both ridge crests and troughs was considered, in the hope that this might enable an estimate to be made of any flattening in the ridges in the time that has elapsed since they were formed. A preliminary examination of the ridges showed however that trough depths are almost entirely irregular and bear little relation to ridge height and age. Troughs are generally deepest at bends when the newer ridge sometimes lies a considerable distance seaward of the preceding one, a characteristic of recent ridge patterns at the Ness. Occasional deep lows, locally called pits and con-

[1] Lewis, W. V., "The formation of Dungeness Foreland," *Geogr. J.* 60 (1932) 318.

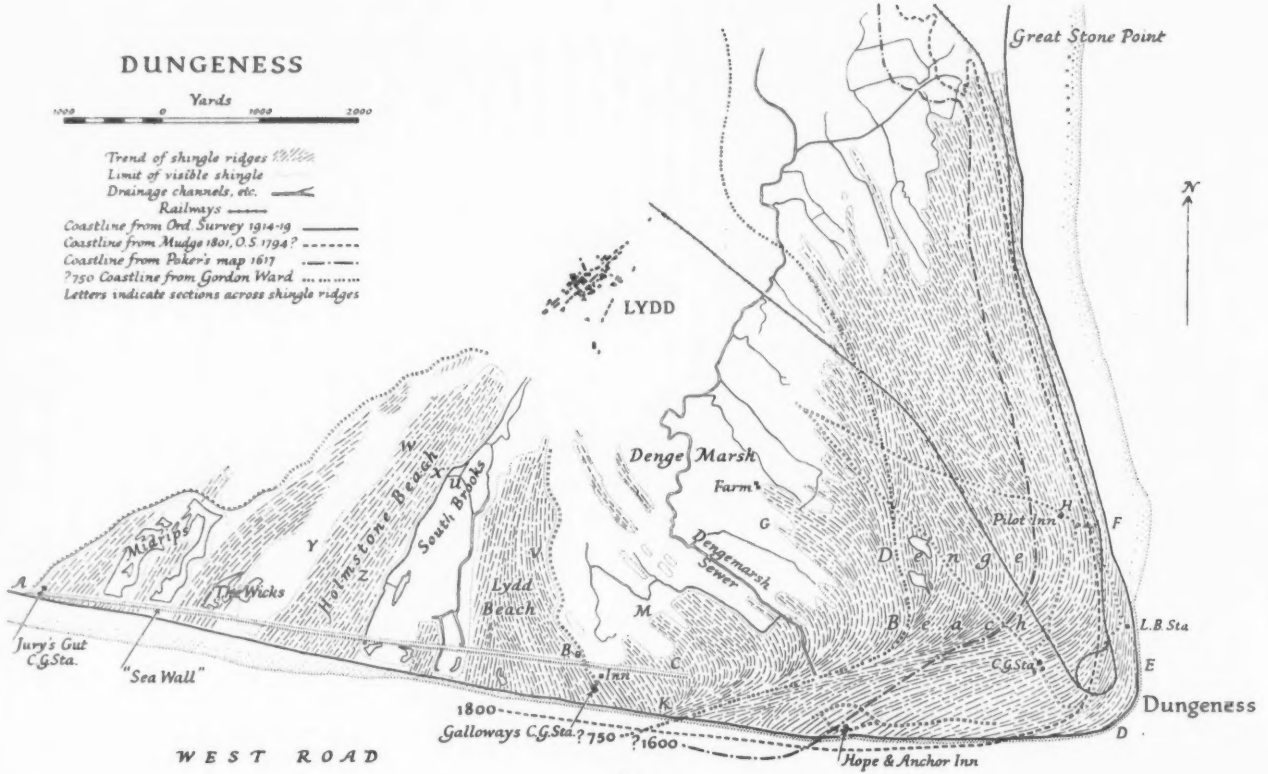

DUNGENESS
Yards
1000 0 1000 2000
Trend of shingle ridges
Limit of visible shingle
Drainage channels, etc.
Railways
Coastline from Ord Survey 1914-19
Coastline from Mudge 1801, O.S. 1794?
Coastline from Poker's map 1617
?750 Coastline from Gordon Ward
Letters indicate sections across shingle ridges
Great Stone Point
N
LYDD
Denge Marsh
Farm
Pilot Inn
H
F
G
Dengemarsh Sewer
Denge Beach
L.B Sta
E
Dungeness
D
Hope & Anchor Inn
Galloways C.G.Sta.
?750
?1600
1800
K
Inn
C.G.Sta.
B
C
M
Lydd Beach
South Bybuks
Holmstone Beach
W
X
U
V
Y
Z
Midrips
The Wicks
A
Jury's Gut C.G.Sta.
"Sea Wall"
WEST ROAD

Fig. 1

taining water, are scattered about amongst the shingle. They were usually found during rapid prograding to the lee of bends. Trough depths were not therefore taken.

AB (Fig. 2) shows the ridge heights of the traverse from Jury's Gut Coastguard Station, along the flood wall, to its end south of Denge Marsh. The oldest ridges levelled are those within 400 yards of the start. The surface of the shingle is here so flat that it was difficult to determine the ridge crests. An indication was given by the parallel lines of relatively fine and coarse shingle—the coarse marking the old troughs and the fine the crests. The reason for this very characteristic distribution of material can be seen on the modern shore. During periods of normal weather conditions, when moderate-sized waves break on the shore and the alternations of spring and neap tides bring the waves into contact with all but the highest parts of the beach, the coarser material is gradually pushed up to the top of the beach where it forms a low ridge, or more often a terrace, in front of the higher ridges. This sorting is due to the well-known tendency of breaking waves to sweep large and small shingle alike up the beach with the powerful send, especially if the waves are constructive in type, but to return a greater proportion of smaller shingle with the backwash, which has lost much of its power through friction and percolation.[1] When powerful storm waves occur however they comb down a great deal of material, giving the shore a flatter slope between high- and low-water marks, but throw some of this material up into a storm ridge. This will contain large and small shingle alike as the storm waves dig deeply into the beach and thoroughly mix the material. Thus a ridge of mixed debris will be formed on the seaward side of a flat, relatively low, area of predominantly coarse shingle. And so the alternating series of fine and coarse lines is formed.

The ridges near Jury's Gut vary between 14·13 and 12·15 feet above Ordnance Datum and fall in height towards the Midrips. The main group averages 13·5 feet. Only two low ridges in the Midrips could be measured rather near their ends, giving 13·07 and 12·15 feet. Then follows a series of nine, very uniform in height and very flat between crest and trough, averaging 13·75 feet. The low flooded area of the Wicks is succeeded by the massive Holmstone Beach on which forty ridges were levelled. Here there is somewhat greater variation in the heights of the ridges and also clearer distinction between ridges and troughs. The first few ridges are very low, but they end only just north of the levelled line; the same applies to the last of the series. The highest ridge is at 15·58 feet and the average is 14·14 feet.

East of Holmstone Beach is one of the largest areas relatively free from bare shingle. It is over half a mile wide at its southern end and extends northwards to Lydd. It has distinctly less area below the water table than either the Wicks or Midrips, and bare shingle shows up at several places, whilst south of the flood wall recurved ridges are nearly continuous. On one fairly large area of shingle a reading of 15·86 feet was taken. Then follows Lydd Beach, similar in outline to Holmstone Beach. There is considerably greater variation in the height of these ridges than the preceding ones, and the troughs are very much deeper. In these respects this set of shingle ridges resembles closely the more

[1] Cornish, Vaughan, "On sea beaches and sand banks," *Geogr. J.* 11 (1898) 534.

Fig. 1

recent areas of Denge Beach. About 400 yards along the route the ridges of Lydd Beach are definitely lower than the average and just to the south is a flooded low. The lower of the remaining ridges end a little to the north of our route; the ridges are thus not as continuous as in the Holmstone Beach. The highest ridge of this series is at 16·53 feet, and the average height of the main ridges is 15·4 feet.

The Ordnance Survey mark the following series of spot heights across the same ground a little to the north of our route (Fig. 2):

Beaches west of the Wicks	13, 15, 13
Holmstone Beach	15, 13, 16
South Brooks	8, 11, 8, 11, 6, 9
Lydd Beach	16, 13, 15, 13, 15

These results agree closely with our own, but it is not known whether or not the Ordnance Survey took the crests of the ridges. Colonel Behrens arranged for three lines of levels to be taken on the Holmstone and Lydd beaches, in which the heights and distances apart of crests and troughs were recorded. The location of these lines is shown in Fig. 2 together with the results. The heights shown on section W–X are similar to those of the Ordnance Survey and to our results for Holmstone, but section Y–Z is systematically lower by over 4 feet, for reasons which at present cannot be surmised. The ridges near the eastern end of section U–V are a foot higher than on our route, but otherwise there is agreement.

To the east of Galloways Coastguard Station are some of the lowest ridges levelled; they end near the flood wall and their height (section K–M, Fig. 2) averages 12·5 feet. The last one rises to 16·78 feet and heralds the most conspicuous rise in the whole area—marked by the end of the flood wall, built to keep the water which washes over the southern shore during storms from flooding the marshes. The wall is no longer necessary farther east where high ridges back the shore. The levelled line is continued, after a small gap, in section C–D (Fig. 2). The first ridges of this series average little over 15 feet and bend sharply where the route crossed them. As the ridges straighten out they increase greatly in height to 19·5 feet at N and a maximum of 20·63 feet at P, the greatest height reached by any of the laterals on the southern route. Thus the ridges rise from 12·5 to over 20 feet in a few hundred yards. The higher ridges have been thrown back over the earlier lower ones and at the same time extend successively farther to the east and north. The ridges marked N overlap the full length of Denge Marsh on the east. There is then a rapid fall in level to 15 feet but with a rise to 17·5 feet at Q, falling again to about 16 feet. This is followed by an intermittent but distinct rise in level to nearly 20 feet at R. The whole series from N to R cross the route as straight parallel ridges. To the east of R the ridge heights fluctuate between relatively narrow limits and average 18·5 feet, whilst the points levelled become nearer to the bends in the ridges.

Section G–H (Fig. 2) was chosen as it crossed over one hundred ridges where they had rounded the bend and followed nearly straight parallel courses. They correspond roughly in direction, and probably also in relation to the bend, with those levelled in Holmstone and Lydd beaches. In order

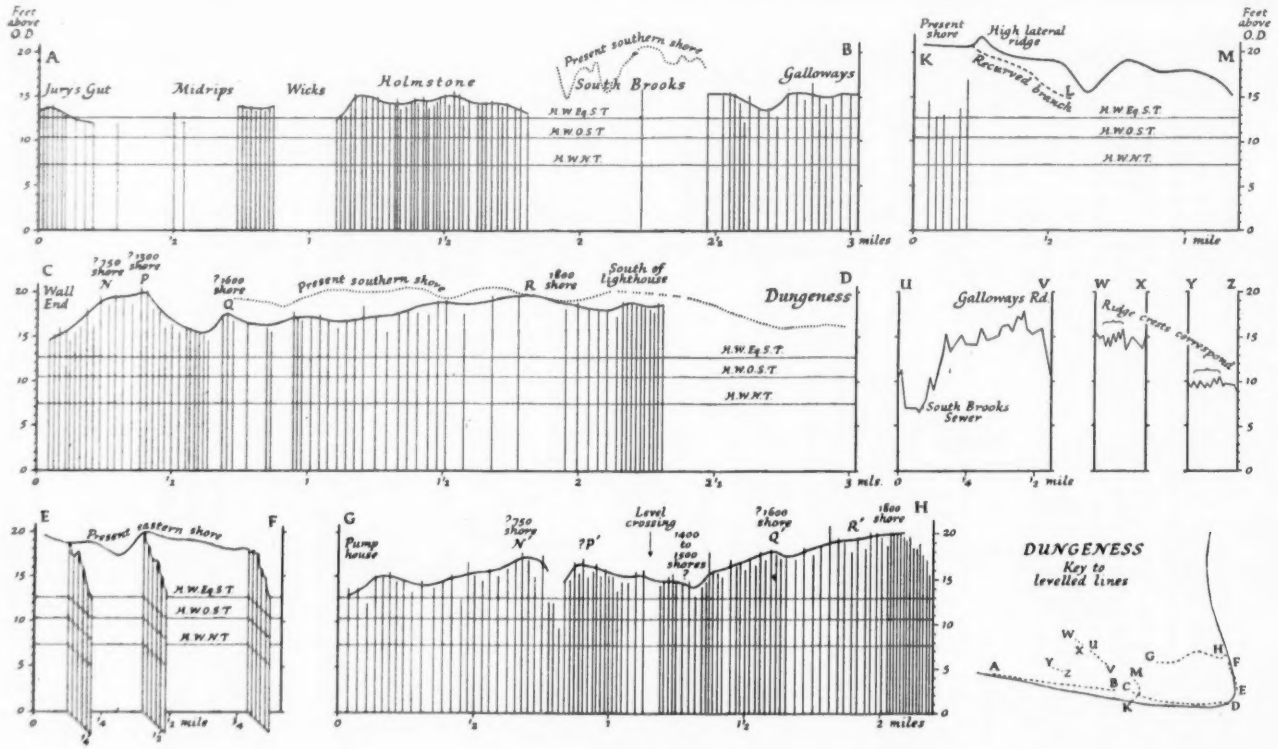

Feet above O.D
A
Jurys Gut
Midrips
Wicks
Holmstone
Present southern shore
South Brooks
B
Galloways
H.W.Eq.S.T
H.W.O.S.T
H.W.N.T
3 miles
Present shore
High lateral ridge
Recurved branch
K
M
1 mile
C
Wall End
?750 shore N
?1500 shore P
?1600 shore Q
Present southern shore
1800 shore R
South of lighthouse
D
Dungeness
3 mls.
U
V
Galloways Rd.
South Brooks Sewer
W
X
Y
Z
Ridge crests correspond
½ mile
E
Present eastern shore
F
G
Pump house
?750 shore N'
?P'
Level crossing
1400 to 1500 shores ?
?1600 shore Q'
1800 shore R'
H
2 miles
DUNGENESS
Key to levelled lines

Fig. 2

to indicate which ridges on this route correspond with those on the previous line, the points N, P, Q, R are marked as N′, P′, Q′, R′ in section G–H.

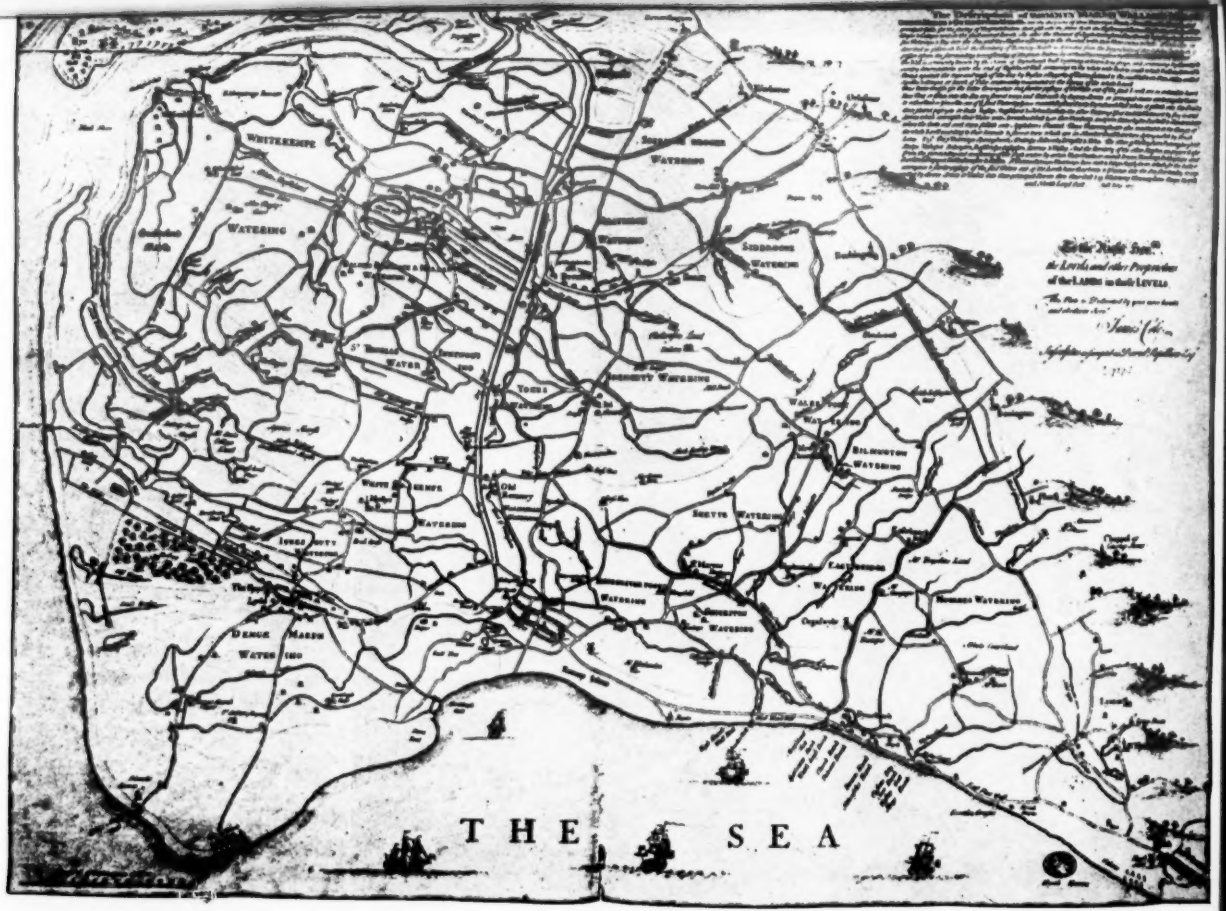
Near G many ridges correspond with each one of the previous route, whereas the reverse is true near H. The first three ridges of the section were measured very near their ends, and they soon rise to just over 15 feet. Then come six all below this height, which are shorter ridges and lie near a series of vegetated lows. Excluding the next ridge but one, which borders another low, the succeeding ridges oscillate about the 16-foot mark as far as N′; then they rise to a maximum of nearly 18 feet before falling abruptly to a very low level with a minimum of 9·47 feet. This corresponds with two extensive water-filled lows, just south of the line of levels, which are the most striking natural features in the whole of Denge Beach. The plan of the ridges suggests that these low ones are absent from the southern section, and this is indicated by the levelling. After recovering from this exceptionally low level the ridges reach a secondary maximum at P′, then fall gradually from 17 to 15 feet at the level crossing and to an average of 14 feet a few hundred yards farther east. The ridges then show an unmistakable rise almost to the present shore. Two ridges however, one 400 yards west and the other a similar distance east of Q′, rise fully 2 feet above the rest. The ridges average 17·5 feet at Q′, reach 20 feet a little to the east of R, and very nearly maintain this height to the present day. The last six ridges can be discounted as they form the upper slopes of the present foreshore, and a severe storm from the east would certainly overwhelm them and probably increase the height of the ridge behind.

Dating the ridges

The shingle ridges shown on Fig. 1 represent some of the positions successively occupied by the shore-line in the last few thousand years. There is probably no absolute way of dating the majority of them; if we start with the modern shore and work back in time we pass from zones which can be dated accurately to those whose dating is largely a matter of speculation. The attempt however might be justified provided the results are treated with due caution.

The coast-line is based on the 1914–19 revision of the 1-inch Ordnance Survey map. Since that time many yards have been lost from the southern shore, and an amount varying between 0 and 100 yards added to the eastern shore; but 1914–19 appears to be the last date on which the whole coast-line was mapped. The 1800 shore is added from the 1-inch map of the County of Kent, published by W. Faden in 1801 under the direction of W. Mudge and based on a trigonometrical survey by the Ordnance Survey in 1794. The maps of pre-Ordnance Survey days are disappointing for our present purposes, as standards of accuracy are far lower. With the kind assistance of Mr. H. R. Mallett, Map Curator of the Cambridge University Library, about twenty early maps were examined, covering a period A.D. 1600–1800, and these, together with old maps of Kent referred to in various publications in *Archaeologia Cantiana*, probably include much of the information at present available in old maps.

It is perhaps advisable to start with the earliest maps and work forward in time, although this temporarily reverses our sequence. Probably the earliest



Cole's reproduction of Poker's map of Romney Marsh

map showing Dungeness on a reasonable scale is the Kent section of the 'Mappae Geographicae Angliae,' by Laurence Nowell, Dean of Lichfield, dated about 1566.[1] This however cannot be relied on as it shows the coast north of Dungeness straight, ignoring Dymchurch Bay, which certainly existed at that time. In 1570 came Glover's map published as a frontispiece to Lambarde's 'Topographical Dictionary.'[2] This, like Saxton's Kent which followed it in 1575, is crude in its representation of Dungeness, showing it rather like a snout projecting too far to the east, and there is no differentiation between marsh and shingle. In view of the importance of Saxton's survey of the country as a whole,[3] it is disappointing to find his map of little use; he shows Lydd too far to the south, New Romney due north of Lydd, and Old Romney 3 miles north-west of Lydd, all positions being grossly in error. It is fortunate that in Kent, alone amongst the English counties, Saxton's survey was greatly improved upon by Phil Symonson in 1596, whose works have received high praise from his contemporary Lambarde; this Society possesses the earliest known issue of the whole map. The shingle is clearly shown and also the trees on Holmstone Beach, but Dengemarsh sewer is too far west, and unfortunately the least accurate section of the shore of south Kent is that of the shingle area of Dungeness Foreland. The Ness, though far better than on earlier maps, still projects too far to the east and is more pointed than any of the early shore-lines indicated by the ridges; it is shown about half a mile to the east of the present position. The lack of details on the shingle area is a handicap, though the Cabons, precursors of the cluster of fishermen's huts round the modern Pilot Inn, agree in position with that shown on M. Poker's map of 1617 mentioned below. The county of Kent in Speed's 'Theatrum Imperii Magnae Britanniae' (1616) represents a slight retrogression from Symonson to Saxton and Glover.

This is followed by quite the most useful early map: M. Poker's map of Romney Marsh, 1617, the original of which is in the Maidstone Museum. Dr. Gordon Ward used this map to help in placing the fleets mentioned in certain Saxon Charters of Burmarsh,[4] and he further writes: "Poker's map is badly drawn but I think reliable in other particulars." This map is reproduced in a paper by F. W. Cock,[5] together with James Cole's early eighteenth-century engraving of Poker's map. The latter (see Plate) is a faithful copy of the original and much better drawn, and the ? 1600 shore-line in Fig. 1 has been taken from it. Round figures have been used throughout, in referring to this and other shores, in order to avoid the suggestion of too great precision in the dating. Several other factors suggest that we can accept the shore-line with some confidence. Distances from Lydd of various features near the shingle areas are accurate on Poker's map and many features, such as farms, tracks, and sewers, with their various bends, can be located to-day. Poker's shore-line also shows two well-marked re-entrants, the one at the outfall of Dengemarsh

[1] Livett, G. M., "Supplementary note on early Kent maps," *Archaeol. Cant.* 50 (1938) 140.

[2] Livett, G. M., "Early Kent maps," *Archaeol. Cant.* 49 (1937) 251.

[3] Fordham, G., 'Notable surveyors,' Cambridge, 1929, p. 5.

[4] Ward, G., "The Saxon Charters of Burmarsh," *Archaeol. Cant.* 45 (1933) 136.

[5] Cock, F. W., "The oldest map of Romney Marsh," *Archaeol. Cant.* 30 (1914) opp. p. 224.

sewer (a natural result of the holding up of the eastward-drifting shingle and just noticeable in the present shore) and the second between the Pilot and Great Stone Point. A map-maker of the calibre of Poker would readily have observed these features of the shore-line, though he might be guilty of foreshortening. Both of these re-entrants can be traced in the ancient ridges near, though not exactly on, the ? 1600 shore-line in Fig. 1. The fact that the ? 1600 shore-line does not follow the shingle ridges shows that it is only approximately correct. Corresponding with the points where the levelled lines cross this shore-line are two equal maxima in the ridge heights which are marked as Q and Q′.

None of the maps examined for the next two centuries inspire sufficient confidence to allow us to draw in a shore-line between that of 1600 and 1800. Dugdale, in his 'History of imbanking and drayning,' 1662, uses a map of Romney Marsh and Dungeness similar to Poker's but less accurate, distances along the two main routes from Lydd towards Dungeness being exaggerated. In 1719 comes a map engraved by Samuel Parker with the title "A New Map of Kent." The shore-line, compared with Poker's, shows an advance at Dengemarsh sewer outfall of 150 yards, but a retreat of 300 yards at the Pilot Inn and of a lesser amount at Dungeness; New Romney is also shown much too close to Lydd. A ½-inch map of the County of Kent, claimed as having been surveyed by John Seller about 1775, as far as Dungeness Foreland is concerned is merely a copy of Phil Symonson's map of nearly two centuries earlier, with hardly any alteration. A 2-inch map of the County of Kent, surveyed by Andrews, Drury, and Herbert, and published in 1779, is an exact copy of Poker's map as far as the coast-line and much detail is concerned, with an improvement only in representing changes in sewers and bridges. A map of the County of Kent on a scale of rather less than half an inch was published by W. Faden in 1796. The shore-line both at Dengemarsh sewer outfall and at the Pilot is 150 yards to the seaward of Poker's shore, but although distances elsewhere on the map are accurate the shape of Dungeness between the above two points is very different from any suggested by the ridges themselves. By this time the trigonometrical work of the Ordnance Survey becomes available.

Another line of evidence gives some indication of the shore in the eighth century. Denge Marsh, according to Holloway's 'History of Romney Marsh,' published in 1849, had been reclaimed by the middle of this century, so that there must have been shingle to the east of this area to give protection from easterly storms. Dr. Gordon Ward, who has done much to elucidate the topographical changes in the Romney Marsh area from a study of Saxon Charters,[1] in a paper dealing with Saxon Lydd [2] attempts to reconstruct the sea shore in A.D. 744. The first and more important of the two charters dealt with by Gordon Ward was that of A.D. 744, by which Offa made grants of marsh land near Lydd to the Church of Christ in Canterbury. Unfortunately the wording of this charter was vague and it gave rise to many disputes, but a record of one of these disputes with the Corporation of Lydd in 1460 defines

[1] "The Wilmington Charter of A.D. 700," *Archaeol. Cant.* 48 (1936) 11. "Sand Dunes Boc," *ibid.*, 43 (1931) 39. "The river Limen at Ruckinge," *ibid.*, 45 (1933) 129. "The Saxon Charters of Burmarsh," *ibid.* 15 (1933) 133.

[2] Ward, G., "Saxon Lydd," *Archaeol. Cant.* 43 (1931) 29.

the grant of land more precisely. This evidence, together with that of a charter of A.D. 740 in which Aethilbert, King of Kent, granted certain lands and rights to the Monastery at Liminge, enables Gordon Ward to construct his map.

His shore-line strikes the shingle at the northern end of our ? 750 shore, and we drew the latter so as to follow the ridges from this point to the southern shore. The points where this ? 750 shore crosses the lines of levels are indicated by N and N′, section CD and GH, Fig. 2. The ridges west of these points get rapidly shorter until the recurves of those immediately south of Denge Marsh and just north of the present shore. These ridges are also about 7 feet below both the modern shore ridge and the high ones N P, so that it seems reasonable to suppose that they correspond with the low sea-level of Roman times referred to below. At present one can only guess the age of the extensive series of shingle ridges farther west from a comparison with the time taken to build approximately equal areas farther east. On this basis, and taking into account the large area which has been lost to the sea, a time interval of about two thousand years would seem to be required. This brings us to the earliest shore-line of which there is clear evidence on the ground to-day. It is marked in Fig. 1 a little to the north-west of the position shown in an earlier paper in this *Journal*,[1] for since 1932 a fairly continuous series of vegetated ridges [2] has been examined on the north-west side of the Lydd to Jury's Gut road, which are not shown on the Geological Map. Everywhere along this line shingle ridges, mostly grassed over, are clearly visible on the ground. They run just east of Jury's Gut, through Lydd Rectory grounds and Lydd Railway Station, then follow the main road to the bend half-way between Lydd and New Romney, continue between the road and Denge-marsh sewer, and finally end in recurves barely half a mile from New Romney. The gap south of New Romney represents an old outlet of the Rother, and from here north-eastwards the old shore ridges follow the main road to the point where it joins the modern shore. This shore-line has been commented on by many of the early writers [3] on the problem of Dungeness Foreland, as it marks an important topographical break, all to the west being drained marshland at a much lower level. A good impression of this change of level is gained if one examines the gradient on the railway as it falls in level from Lydd Station to Walland Marsh on the west and to Denge Marsh on the east. This ancient shore-line forms a major stepping-stone in the evolution of the area. It is assumed [4] to be the shore formed when the sea-level rose to near the present and drowned the 25-foot submerged forest.

Attempts to estimate the age of the ridges by the nature of the vegetation cover or spread of lichens and moss over the individual pebbles have proved very misleading. A large number of factors other than age, such as distance and direction from the nearest marshes, grade of shingle, depth of water-

[1] Lewis, W. V., "The formation of Dungeness Foreland," *Geogr. J.* 60 (1932) 310.
[2] This shore-line is shown correctly by Lewis, W. V., "The formation of Dungeness and Romney Marsh," *Trans. S.E. Union. sci. Socs.* 42 (1937) 65.
[3] Elliot, J., "Account of Dymchurch Wall," *Min. Proc. Inst. civ. Eng.*, vol. 6, p. 466.
[4] Gilbert, C. J., "The evolution of Romney Marsh," *Archaeol. Cant.* 45 (1933) 252. Lewis, W. V., "The formation of Dungeness Foreland," *Geogr. J.* 60 (1932) 318.

table, have great effects which cannot as yet be assessed. Mr. R. T. Pearl, head of the Botanical Department at Wye Agricultural College, who is at present working on the spread of vegetation, has informed us of the complex nature of the problem.

Rate of growth of Dungeness

Lest this highly speculative attempt to date some of the shore-lines should lead one to consider that the growth of the ridges has been more or less uniform, some of the available evidence of the rate of growth for the Ness is given below.

Redman [1] summarized much of the evidence up to his time, and the following table is based on his paper:

Date	*Distance from Lydd*	*Authority*	*Average annual growth*
Elizabethan ..	3 miles		
1617	$3\frac{1}{8}$	Cole	5 yards
1689	$3\frac{1}{4}$	Collins	3
1794	$3\frac{3}{4}$	O.S.	$8\frac{1}{4}$
1809	$3\frac{3}{4}$	Graeme Spence	None
1844	$3\frac{7}{8}$	Redman (?)	$4\frac{1}{2}$ yards

Thus there appears to have been a growth of at least 6 yards per annum from 1617 to 1844, and Redman considered the varying rates to be partly real and partly due to inaccurate estimates.

In 1860 Drew [2] measured an advance of 360 yards since the mapping of the Ordnance Survey. Gulliver [3] states in 1897 that the Ness was advancing 3 yards per annum, and Johnson, in 'Shore processes and shoreline development,' 1919, quotes a coastguard officer who estimated the advance as 20 yards per annum. Unfortunately Johnson followed Gulliver in assuming that Drew's Geological Survey Map shows all the ridges, and his estimate of the rate of growth of individual ridges is wide of the mark.

The variable rate of growth is well illustrated by the recent mapping of the eastern shore by Mr. S. Swallow, of St. Catharine's College, Cambridge, who has kindly allowed us to use the full results on which were based his remarks in a recent discussion in this *Journal*.[4] The following table, indicating aggradation at various points on the eastern shore, is based on the 1871 and 1908 editions of the 6-inch Ordnance Survey, and on Mr. Swallow's mapping of 1938 and 1939.

Distance north of Ness in yards	*Growth in yards*			*Average yards per annum*
	1873–1908	1908–38	1938–39	1878–1938
—	137	148	−5	$4\frac{1}{2}$
200	123	108	9	$3\frac{1}{2}$
800	92	84	1	3

[1] Redman, J. B., "Alluvial formations of the south coast of England," *Min. Proc. Inst. civ. Eng.* 2 (1851–52) 15.

[2] Drew, F., "Geology of the country between Folkestone and Rye," *Mem. Geol. Surv. U.K.*, p. 22.

[3] Gulliver, F. P., "Dungeness Foreland," *Geogr. J.* 9 (1897) 539.

[4] Steers, J. A., etc., "Recent coastal changes in S.E. England: a discussion," *Geogr. J* 93 (1939) 505.

Distance north of Ness in yards	*Growth in yards*			*Average yards per annum*
	1873–1908	1908–38	1938–39	1878–1938
1340	82	73	—	2½
1700	75	15	—	1½
2150	67	0	—	1
2800	77	−7	—	1
3230	57	10	—	1
3860	30	33	—	1
4420	33	25	—	1
4920	23	20	—	½
5420	13	15	—	½
5920	12	13	—	½
6210	15	3	—	¼
6660	60	3	—	1

The faster growth of the Ness, clearly brought out in this table, is also evident in Fig. 1 by the lack of parallelism between the 1600 and 1800 shores.

Factors affecting the height of ridges

The building of shingle ridges on a shore-line has been discussed in an earlier paper in this *Journal*,[1] and for our present purpose can be summarized as (*a*) the supply of material by the oblique waves of normal weather conditions and the subsequent depositing of this material on to the upper foreshore by constructive waves, and (*b*) the throwing up by storm waves of some of this debris into great ridges at the top of the beach. Given sufficient material it would seem that the height to which the advancing waters—send or wash—from the storm breakers would pile the shingle depends on the power of these waves, the height of the mean water surface at the time, and the grade of the material; for with large pebbles the gradient of the upper foreshore is steeper than with a fine gravel, and so the send from the storm breakers is deflected upwards to a greater height. The storm beaches of the Bristol Channel, with a tidal range of 40 feet, rise high above mean sea-level, but are greatly exceeded in height by the Chesil Beach with its tidal range of only 10 feet but far greater storm waves. Johnson [2] considers that the height of ridges is largely dependent on the rate at which they are built. With a rapid supply of debris he considers that the shore-line might be prograded so fast that a given ridge has little opportunity to grow to a great height before the shore-face zone is shallowed and a new ridge is formed in front. This is clearly demonstrated in the ridges of Dungeness Foreland, but nevertheless the maximum height—as opposed to the average—would seem to depend largely on the maximum size of storm waves, for a great ridge can be the product of a single storm, given sufficient material. At Dungeness, where each new ridge seems to have been added every two to ten years, exceptional ridges rise well above the average level, but where the rate of growth is much slower each ridge is equally high.

[1] Lewis, W. V., "Effect of wave incidence on configuration of a shingle beach," *Geogr. J.* 78 (1931) 131.

[2] Johnson, D. W., 'Shore processes and shoreline development,' New York, 1919, p. 413.

From information kindly supplied by Dr. J. N. Carruthers, Director of the Fisheries Laboratory, Lowestoft, and from an Admiralty Chart,[1] it has been possible to add in Fig. 2 the approximate position of Mean High Water Springs (10·5 feet above Ordnance Datum) and also Mean High Water Neaps (7·5 feet above Ordnance Datum), while the horizontal line at 12·7 feet above Ordnance Datum represents Equinoctial Spring Tides. Thus there is a difference of over 5 feet between the high water for neap tides and that for equinoctial spring tides. It is evident therefore that the time at which a great storm occurs is a matter of importance. In addition it raises the sea-level locally besides producing powerful waves, as is illustrated by the 1938 Horsey Floods when the sea-level was 7 feet higher than during an ordinary spring tide.[2] The evidence of Chesil Beach suggests however that size of storm breakers determines largely the height of ridges, and the factors influencing the size of storm breakers should be borne in mind.[3] The most important are: the stretch of open water, depth of water offshore, and curvature of the shore. Shoaling water absorbs the wave energy by bottom drag and retards the wave fronts, the resulting refraction causes great loss of energy whenever the wave becomes curved convex to the shore, for the energy then has to be spread over an ever-widening front. Chesil Beach well illustrates some of these relationships. It presents a long straight shore-line directly facing the Atlantic, and this, together with the deep water immediately offshore allows larger waves to reach it, and there is ample material available. Accordingly the main ridge has been thrown up to a height of 43 feet above high-water spring tide,[4] greatly exceeding that of any other shingle embankment in the country and possibly in the world. Further, Chesil and Hurst Castle Spit, at the mouth of the Solent, increase in height to the south-east,[5] *i.e.* at the ends most exposed to the dominant south-west waves. Of the above factors a sufficiency of material can safely be assumed at Dungeness; length of fetch is readily determined; curvature is self-evident; depth of water in early times is speculative, but near the shore it is largely a function of the waves themselves; strength and constancy of storm winds is uncertain and it must be assumed, for lack of evidence to the contrary, that the tidal range has remained constant. The height of a single storm ridge thus indicates very little with regard to change in level of land and sea, but when one has ten or more ridges under consideration in each group, and the above factors are carefully borne in mind, the evidence seems to indicate a real change of level.

An examination of the heights of certain ridges which were levelled in order to provide a control in interpreting the results of the main series, best illustrates the relative importance of the complicating factors cited above. The modern ridge along the southern shore was levelled for 2½ miles, and that

[1] The Approaches to Dover Strait, Admiralty Chart 1431.

[2] Mosby, J. E. G., *Geogr. J.* 93 (1939) 417.

[3] Lewis, W. V., "The evolution of shoreline curves," *Proc. geol. Ass. Lond.* 49 (1938) 109.

[4] Coode, J., "Description of Chesil Bank," *Min. Proc. Inst. civ. Eng.* 12 (1852–53) 533.

[5] Redman, B., "Alluvial formations of the south coast of England," *Min. Proc. Inst. civ. Eng.* 2 (1851–52) 36.

along the eastern shore for just under a mile, and the results are shown in the sections AB and CD of Fig. 2. The section included in AB was levelled at 30–50-yard intervals and shows maximum variations of 2½ feet from the mean, together with several lesser variations. The first of the two low levels corresponded with a break-through where recent storms had washed over the bank, and the second with a local area of marsh which backed the shore. Here, presumably, shortage of material caused the fall in level, for this southern shore is retreating and so the supply for building the main ridge is largely derived from the erosion of the old lateral ridges. The higher eastern half was backed by shingle. In section CD the height of the main ridge of the southern shore from the Hope and Anchor Inn to Dungeness is shown. The variation from the mean to the west of the Ness reaches a maximum of 1 foot and averages less than 9 inches. This uniformity is real and not due to staff positions being farther apart; it probably reflects the fairly level surface of the shingle ridges and troughs backing this part of the shore. As the Ness is approached the level falls steadily just over 4 feet and remains at this level around the bend. The ridge has therefore been thrown to a height of 8½–10 feet above Mean High Water Springs, and at the bend this amount falls to 5½ feet. These differences are probably due to curvature and to the greatly diminished length of fetch off the Ness, which becomes reduced from 125 miles in a south-south-westerly direction to 30 miles towards the east-by-south, and rises to 100 miles in a direction east-by-north, that faced by the eastern shore.

Section EF (Fig. 2) shows the height of ¾ mile of the main ridge of the eastern shore from the Pilot Inn to just short of the Ness. At three points ridge heights—but not distances apart—were taken along transverse sections down the foreshore, and this enables the three sections across the lower ridges, of calmer weather or neap tides, to be drawn. The main ridge shows a maximum variation from the mean of 1 foot 3 inches, but an average of far less than this. This variation can no longer be attributed to differences of height of laterals behind the shore, for aggradation is here taking place and the successive ridges lie nearly parallel. The lower ridges on the foreshore vary in height to some extent independently both of each other and the main ridge; and the lowest ridge is subdivided at its southern end. These characteristics appear in many of the old ridges behind this shore; they bifurcate and rejoin, even when nearly parallel, so that it is seldom possible to trace a single ridge for any great distance. When the ridges are not parallel they follow the most complex patterns. Section KM shows a portion of the southern shore, and two lateral ridges in a very critical area south of Denge Marsh (see Fig. 1). The modern ridge increases in height by over a foot in front of the main lateral, which was one of the highest of all. On following this lateral north from the modern shore, the level falls rapidly to below 20 feet as one gets out of reach of the present storm waves. The very marked fall in level of about 4 feet corresponds with the bend in the ridge. The ridge-top rises again as it straightens out, though the north-east facing section approaches the height of the south-east facing part at only one point. After maintaining a level of 17½ feet for 300 yards the ridge rapidly decreases in height towards the end. A second parallel recurve was levelled for part of its length and repeats some

of the features of its greater neighbour. The chief difference is that it starts falling in level farther from the bend, probably because it was a more sharply recurving branch of another lateral ridge.

Suggested interpretation of the ridge heights

The ridge heights shown in the sections AB, CD, GH (Fig. 2), exhibit a great number of variations, related no doubt to periods of storminess, changes in the rate of building, and the like. Superimposed on these fluctuations however are unmistakable changes of level which continue for several centuries, and we tentatively suggest that these represent actual changes in the relative level of land and sea. On this assumption we shall attempt to estimate changes in the level of the sea relative to the land in this area. Even if this assumption is justified, which is not yet certain, it should be clear that we do not wish to imply that it is the level of the sea and not the land which has changed; we are concerned here only with the relative changes.

A firm line has been drawn indicating the average ridge heights of each section and tentative dates for the different stages of ridge building have been added from the evidence given above. The most marked change is the steady fall in level in section GH from the latest shore ridges to those built at a time estimated to be in the fifteenth century. This represents a more or less uniform fall of 6 feet, averaging slightly over 1 foot a century. This fall in level is repeated in section CD from R to just west of Q, the rate being the same as in the preceding section in spite of the greater extent of the shingle in this area between Q and R.

East of R however the ridges fall in level, presumably because the levelled points get successively nearer to the bends in the ridges. The manner in which this bend lowers the modern shore ridges is shown at the east end of section CD, and the east end of section GH might therefore be expected to give a truer indication of any change of level than do the corresponding ridges in CD.

That this fall in ridge level from the modern shore to about the fifteenth-century ridges might indicate a change in sea-level is supported by recent analyses of tidal data. Jolly [1] in his examination of the annual mean sea-levels at Newlyn and Felixstowe from 1916 to 1935 and in a more detailed study of the monthly values for 1917–19 and 1934–37 found two converging lines of evidence indicating that between these dates the sea was rising relative to the land at a rate of a foot a century. Jolly further considered that these amounts agreed with the supposed rise of sea-level in the lower Thames of about 15 feet since Roman times.[2] The ridge heights at Dungeness, on the other hand, suggest that this rise in sea-level has continued only from about the fifteenth century.

From Q to N, in section CD, the ridges are very compressed, so that each ridge corresponds with a whole series of ridges farther north. Thus the distance between the ? 1600 shore and the ? 750 shore is very short. West of Q

[1] Jolly, H. L. P., "Supposed land subsidence in the south of England," *Geogr. J.* 93 (1939) 408.

[2] Wheeler, R. E. M., Roy. Comm. on Hist. Mon., vol. III, 1928, 'Roman London,' p. 13.

the ridges reach a maximum of 15·5 feet, farther west they rise rapidly to fully 20 feet and then fall to about 19·3 feet at N. Do these ridges indicate changes of sea-level? There is much evidence that in the thirteenth century sea-level was fully as high as to-day in the Dungeness area. The early itineraries and chronicles describe in great detail the series of storms of the twelfth and thirteenth centuries, culminating in that of 1287 which finally destroyed Old Winchelsea and Promehill, diverted the Rother outlet from New Romney to near Rye, and flooded all the marshes south of the Rhee Wall. New Romney which, like the other marsh settlements, is built on old beach ridges well above the general level of the marshes was flooded, and after the waters subsided nearly 4 feet of silt had been deposited in the Norman Church of St. Nicholas and the ground surrounding the church had been raised by a similar amount.[1] According to figures for which the authors are indebted to the Vicar of New Romney, the Rev. Arthur H. Dolphin, several steps at each entrance to the church now lead down the 3 feet 2 inches from the present level of the street and churchyard to that of the church floor; while the street level below a bench mark on the foot of the tower is at 16·4 feet above Ordnance Datum (Newlyn) a fact which testifies to the height reached by the waters of those great storms. There is no mention of a recurrence of storms of this severity in the succeeding centuries, and a table of storms and floods, compiled from the available records by C. E. P. Brookes in 'Climate through the ages,' 1926, suggests that a period of quiescence followed the storms of the eleventh to thirteenth centuries.

One might reasonably expect to find evidence of such a unique period of storminess in the ridges, and the most likely position seems to be P (section CD, Fig. 2). These ridges (the highest is 20·65 feet) are slightly higher than the eastern ridges to-day, and ridges of this height would seem to be expected from storms which piled silt in New Romney Church to 16·4 feet. Further evidence of the height of the thirteenth-century sea-level comes from Mr. W. Maclean Homan, who has done considerable work on this problem in the neighbourhood of Winchelsea. Mr. Homan has determined, by levelling, the height of the thirteenth-century harbour works on the north-west side of the town and also the base of an old sea-cliff west of Winchelsea. The base of this cliff is exactly at the level of the present highest tides at Rye and the ground in front of it was reclaimed prior to 1330; the height of the old harbour works also suggests that sea-level was then much the same as to-day.

The evidence of a thirteenth-century maximum is not so clear on section GH, Fig. 2, as on the southern route, but there is a well-marked minimum of 14·0 feet which seems to correspond with the ? fifteenth-century minimum already mentioned. West of this the ridges increase in height to a maximum at P′ of 16·5 feet. Then follow some very low ridges, and still farther west comes a maximum of 17·4 feet and a slight fall to 16·5 feet at N′. Thus Q and Q′ seem to be the earliest ridges in the two series which correspond in age and height.

West of Q′ the ridges on section GH are systematically lower than those on the southern route, and it is not possible to trace an individual ridge (say the

[1] Martin, M. E., 'The Church of St. Nicholas, New Romney, Kent,' Ashford, 1929, p. 23.

maximum at P) from the southern to the northern route because of the repeated branching of the ridges. The relatively low elevation of the ridges near P′ is probably due to the levelled positions being near the bends in these ridges and also near the lows of the Open Pits. A section taken north of GH might help to clarify the ridge levels in this area.

West of N′ the ridges fall in level to 14 feet, then rise to 15 feet, and finally fall to 13 feet at G. Both the 14-foot and 13-foot ridges were levelled near their ends and give low readings for this reason. West of N the ridges on the southern route (CD) fall rapidly to below 15 feet and next come the still lower ridges, at an average of 12·5 feet, near K in section KM. Thus there is a fall in level of 7·5 feet in the course of 600 yards, the most marked change in the whole area. The height of the ridges immediately west of N are affected by bends, and similarly those recording 12·5 feet were measured near their ends.

In order to estimate the influence of bends on ridge heights a main ridge, KM, and a branch, KL, were levelled in this critical area. The main ridge dropped 3·5 feet on rounding the bend, but returned to approximately the same height as it straightened out, falling off again by 2·5 feet as it ended. The recurving branch became reduced in height a little before the bend, but otherwise was similar. The ridges, KM etc., which rise so suddenly above those farther west, have also been thrown back over these latter, and it is possible that part of the episode or ridge-building is here missing.

Even if allowance is made for the above factors, this great falling off in ridge heights might reasonably be interpreted as indicating a lower sea-level in times preceding about the eighth century. That sea-level in Roman times was lower than to-day is widely accepted in literature on this subject.[1] Evidence from Dungeness suggests that this movement may have been composite, giving a thirteenth-century maximum, similar to that of to-day, and a level of about 5 feet lower in the fifteenth century. Somewhat similar evidence comes from the other side of the Channel. Dubois [2] found evidence of a renewal of marine deposits continuing until the eighth century, above Roman remains. Might not the increase in ridge heights leading to N and N′ be correlated with this? Chaput, in the 1st report of the Commission on Pliocene and Pleistocene Terraces, 1928, records other deposits containing medieval utensils overlying those of the eighth century noted by Dubois, with yet other deposits above them, thus implying a fall in sea-level between the eighth and thirteenth centuries. This suggests that there might be some significance in the fall in level between N′ and P′ in section GH, Fig. 2. R. D. Oldham, in a discussion of a paper by Steers,[3] also suggested that a widespread rise of sea-level had occurred between the eleventh and thirteenth centuries, and he amplified his evidence in a letter to Gilbert. At least a suggestion of an oscillation in the curve of post-Roman rise of sea-level was

[1] Gilbert, E. W., "The human geography of Roman Britain" in 'The Historical Geography of England before 1800.' Ed. H. C. Darby. Cambridge, 1936, pp. 61 *et seq.*
Jolly, H. L. P., "A supposed land subsidence in the south of England" *C. R. Congr. int. Géogr.* 1938, tome II, sec. IIb, Oceanographie, p. 68.

[2] See Gilbert, C. J., "The evolution of Romney Marsh," *Archaeol. Cant.* 45 (1933) 47.

[3] Steers, J. A., "The East Anglian coast," *Geogr. J.* 69 (1927) 46.

also given by Swinnerton [1] in a paper dealing with the Lincolnshire coast. Further evidence on this point would be very welcome, and it might come from an examination of the levels of the various innings of Walland and Guldeford Marshes, which were reclaimed from about the thirteenth century onwards. A suggestion to this effect has already been made by H. Godwin with reference to the borders of the Wash. Dr. Godwin kindly sent a proof of part of a paper [2] in which he gave Major G. Fowler's views of the evidence of various sea-banks in the coastal area of the Fens, between the present outfalls of the Nene and Ouse. Four successive banks can be traced, and although all except the last, built in 1919, have now been removed, accurate levelling indicates the stepped arrangement of the various innings as they rise to the modern shore. They date from about the tenth century and appear to show "a downward movement (of the land) of perhaps 8 feet in the last 900 years or so."

Assuming that the dating of the ? 750 ridges is approximately correct, those near B, C, and G (Fig. 2) might date from pre-Roman and Roman times, especially as there is abundant evidence that sea-level was then low. If an allowance of 1·5–2·5 feet is made because the ridges averaging 12·5 feet near K were levelled near their ends, they are still 5 or 6 feet below those built about the thirteenth century, and below those of to-day. Does this suggest that Roman sea-level was 5 or 6 feet below that of to-day? Authorities are agreed in claiming a sea-level fully 15 feet lower than the present in the lower Thames, the most convincing evidence being the finding in 1928 of a pile dwelling of the Roman period at Brentford, below the present low-water mark of the Thames.[3] Swinnerton claims a post-Roman rise in sea-level of 9 feet in Lincolnshire, and Gilbert suggested one of about 8 feet at Dungeness. Without such an uplift Gilbert claims that the Rhee Wall could not have accomplished its purposes either of draining or protecting Romney Marsh. Dr. Gordon Ward has suggested that Romney Marsh proper was never reclaimed artificially by the building of the Rhee Wall, but that it became dry land as a result of natural processes. Whether or not this is so, it is agreed that the sea was at a lower level than to-day. The first evidence of occupation is Roman, and it seems probable that it was the low level of Roman and pre-Roman times that facilitated its drainage.

The ridges of Lydd Beach are shown at the end of section AB, Fig. 2. These ridges average over 15 feet, and if some addition is made for slumping it might be assumed that they averaged nearer 16 feet when formed. Might not this suggest that in pre-Roman times the sea was about 4 feet below the present level and 2–3 feet above the Roman level? The major variations in the height of this fairly compact set of ridges are related to flooded lows and recurving ends.

West of Lydd Beach, and next before it in the time scale, comes the compact area of marshes, interspersed with local patches of shingle, known as

[1] Swinnerton, H. H., "The post-glacial deposits of the Lincolnshire coast," *Quart. J. geol. Soc. Lond.* 87 (1931) 368.

[2] Godwin, H., *Philos. Trans. Roy. Soc.* B No. 570, vol. 230, 1940, p. 295.

[3] Wheeler, R. E. M., Roy. Comm. on Hist. Mon., vol. III, 1928, 'Roman London,' p. 13.

South Brooks. In area this marshland almost equals that of Lydd Beach. A few recurved ridges occur south of the flood wall and quite a large area is at the surprisingly high level of over 15 feet. That a ridge of this height did not extend north of the wall is a timely warning against interpreting every low or area of marsh as indicating a fall of sea-level. However the line of Ordnance Survey spot heights already noted on p. 262, taken across Holmstone Beach, South Brooks, and Lydd Beach, about a quarter of a mile north of the flood wall, indicates the real difference in level between these areas.

Thus South Brooks might, as we have suggested for Denge Marsh, represent a low sea-level preceding the formation of Lydd Beach; on this assumption the higher ridges to the south probably represent a period of great storminess from a southerly quarter. The most reasonable alternative is that a great preponderance of waves from a westerly or southerly quarter, with an absolute minimum from the east, might have caused longitudinal extension of this early southern shore without the formation of extensive lateral ridges.

The Holmstone series is still more extensive and continuous than the Lydd Beach, with the higher ridges averaging 15 feet. As the flattening of the ridges here suggests that slumping has taken place, one might reasonably assume that the average height when formed was fully 16 feet above our datum, and thus, if our hypothesis proves correct, represents an early sea-level some 4 feet below the present. The Wicks form quite an extensive flooded low preceded by another long narrow series of ridges, which widens considerably to the north of the Wicks. These ridges average somewhat under 13·6 feet but are very flat; they probably represent a past ridge height of about 15 feet and a supposed sea-level 5 feet below the present. A series of Ordnance Survey spot heights (13, 15, 13) half a mile to the north tend to confirm these values. The few isolated ridges in the Midrips suggest a drop of 1½–2 feet at a minimum and possibly very much more. Finally the earliest and flattest ridges of all are reached; they attain a maximum of 14 feet, and therefore probably represent an ancient ridge height of 15–16 feet. These ridges may also form the southernmost remaining end of the old post-Forest shore-line which extended through Lydd and New Romney, with the contemporary or subsequent break south of New Romney.

If we are justified both in relating the average ridge heights to past sea-levels and in our attempts at dating, then the following changes of sea-level relative to the land seem to have taken place in historic times at Dungeness: a rise in level of approximately a foot a century from about the fifteenth century to the present day; approximately the same level as to-day about the thirteenth century, and a foot or so lower in the eighth century; 5 or 6 feet below the present level in Roman times. Checking is required of both dating and amplitude of these movements, and further information might be forthcoming from other shingle areas such as Orfordness. Little indication of dating prior to 700 is given at Dungeness, though the sequence of events is clear. Both Gilbert's [1] and Swinnerton's references to past sea-levels seem to help here. The low ridges south of Denge Marsh, and the deposition of

[1] Gilbert, C. J., "Land oscillation during the closing stages of the Neolithic depression," 2nd Rep. Comm. on Pli. and Pleist. Terr. 1930, p. 96.

material immediately underlying this area, probably date from the low sea-level of the Roman–Bronze Age period. Both authorities then suggest a rise in sea-level to within a few feet of the present, to which view the levels of Lydd and Holmstone Beaches might lend support. A possible interpretation of the successive beaches and marshes from Galloways C.G.S. to Jury's Gut is that they indicate several oscillations of level from late Neolithic times to the Bronze Age. Before this the sea-level was low for the growth of the forests which were later submerged. This suggestion of oscillation seems to be supported by the findings of Godwin and Clifford,[1] who have demonstrated the oscillatory nature of relative movements of land and sea in this country since Neolithic times.

Perhaps the greatest contribution that the ridge heights can make towards a study of past sea-levels is in suggesting the maximum height of the sea at different times. There is plenty of evidence of low sea-levels from various deposits in different parts of the country, but evidence of high sea-levels is very scanty.

The partial confirmation of portions of the above interpretation of changes of sea-level from authorities taking as varied angles of approach and working in such different localities as Jolly, Longfield,[2] Dubois, Chaput, Gilbert, Swinnerton, and Godwin suggests that both the method and results are worthy of consideration. A clear distinction should be made between fact and deduction in the foregoing remarks, and if deduction has, in places, outstripped the available facts it is our hope that further work will provide the necessary correction.

DISCUSSION

Before the paper the CHAIRMAN (Mr. LEONARD BROOKS) said: This afternoon we are to have a paper by Mr. Lewis, a member of the staff of the Geography Department at Cambridge on "Past Sea-levels at Dungeness." Eight years ago Mr. Lewis read a paper to the Society on Dungeness and I think most of you will remember that in 1939 he was awarded the Cuthbert Peek Grant for physiographical work in Great Britain and Iceland.

Mr. Lewis then read the paper printed above, and a discussion followed.

The CHAIRMAN: About a year ago I went to Dungeness in my car, and half a dozen miles from the Ness itself had to run off the road on to the shingle, which there stood the weight of the car very well; but not far from the Ness, I again went off the road into the shingle, and only with the help of a crane was my car extricated. I did not realize I had gone from the 13th century to the present day.

Mr. Balchin, now working in the Hydrographical Department of the Admiralty, is part author of the paper, and we shall be glad to hear what he has to say.

Mr. W. G. V. BALCHIN: I should like to describe how Fig. 1 was constructed. As Mr. Lewis has already mentioned, the late Lieut.-Col. T. T. Behrens had secured the cooperation of the R.A.F. in the production of an air mosaic of part

[1] Godwin, H., and Clifford, M. H., "Studies of the post-glacial history of British vegetation," *Philos. Trans.* B. 292 (1938) 400.

[2] Longfield, T. E., "The subsidence of London," *Prof. Pap. Ordn. Surv. Lond.*, N.S. No. 14, 1932, p. 3.

Arden-Close, Col. Sir Charles F., "The second Geodetic Levelling of England and Wales," H.M. Stationery Office, 1922.

of Dungeness on a scale of 4 inches to one mile, but that is not now available. We had however the smaller-scale mosaic which faces p. 318 of the previous paper by Mr. Lewis in the *Journal* for October 1932. A close grid of $\frac{1}{8}$ inch squares at 2 inches to one mile was constructed, and proportional grids were laid down on the 1914–19 revision of the Ordnance Survey 1-inch map; on the map published by W. Faden in 1801 under the direction of W. Mudge; and on J. Cole's engraving of M. Poker's map. The coastlines and other detail were transferred to the original grid. Ridge trends only have been indicated, for one cannot follow individual ridges (60 to 100 per mile) on the small-scale mosaic. Fig. 1 shows the results of the levelling and, apart from the coastlines, the general pattern of the ridges. Large-scale ground mapping may be necessary for the proper study of a shingle complex, but these well-defined patterns can be more easily shown on good large-scale air mosaics.

Dr. DUDLEY STAMP: I think the Society should congratulate the authors on presenting the results of observations even if they are, to some extent, negative.

I am not at all clear how these ridges are formed. Have they any relationship to periods of years? If, as Mr. Lewis suggested, a ridge is built up after an abnormal storm, what causes the desertion of that ridge and building a new one? I think Mr. Lewis said a big storm will make the ridges very much higher; if storm action is paramount, may not the widening of the Straits of Dover and the bigger waves during easterly storms have affected the heights of the ridges?

Another point: why 4000 years ago instead of, as I was hoping, the opening of the Straits of Dover as a possible date for beginning the ridge.

Mr. Brooks enquires how far have the ridges been trodden down from their original level. My recollection is that some are very firm and well cemented by vegetation, while others are very loose. Therefore, can one rely on present heights? It surprised me that only the tops of the ridges were regarded and that the depths of the troughs meant nothing: I wonder whether something of importance may have been missed.

Mr. H. L. P. JOLLY: The paper is an interesting mixture of history, archæology, and survey, accompanied by painstaking observations in order to get at the facts which Mr. Lewis has put before us.

When the sea recedes it leaves evidence of what it has done, but when it is getting higher it swallows up all the evidence. I could not see at first how the height of the storm ridges could increase without swallowing up the earlier ones. I can see now that because the existing coast-line is not parallel with the majority of the ridges the protecting wall has been built not along, but at an angle with them, so that unless the sea makes a complete break through, the old contrast of earlier formations is preserved. I think there must be a long time between one high ridge and the next.

I suppose that perhaps half a dozen times each year there is a tide high enough to impress the shore-line, and that if these impressions are about the same height there is some horizontal accretion. Then comes an exceptionally high tide, perhaps only once in fifty years, forming a high crest which remains for all time.

The evidence I put before the Society last year, *Geogr. J.* 93 (1939), 408–413, from the records of a permanent tide gauge, seemed to point to a relative rise of the sea in the south of England: the land is apparently sinking at the rate of about 3 inches in fifteen years. But I would not regard that as a steady rate, in hundreds of years there will probably be considerable fluctuations in relative sea-level. I should not be surprised to find in the record of the last 4000 years evidence of half a dozen marked alternations in the process. This jut of land is

most interesting historically, and there ought to be somewhere some archæological evidence, besides that of New Romney Church, which is certainly conclusive that at that time the sea-level was about the same as it is now.

Mr. R. T. PEARL (Botanical Department, Wye Agricultural College): When I first went there to study the vegetation, I had very little idea of how Dungeness had been formed, what stage it had reached, or of the relative age of the different beaches. Mr. Lewis's work has given me a much clearer picture of what is going on at Dungeness. Workers on Dungeness have suffered a great loss by the death of Colonel Behrens. In addition to the manifold duties of a Garrison Engineer, making roads and railways and dug-outs, looking after buildings and managing agricultural land, supervising drainage of the marshes, and devising coastal protection, he took a real scientific interest in every aspect of the work on Dungeness.

Before I started mine, Colonel Behrens had done much ground work on the vegetation, and my work on Dungeness has been suspended largely because Colonel Behrens is no longer there. Dungeness is some eight or ten miles round the point, and has perhaps 10,000 acres of shingle. These apposition beaches are very bare, largely because they receive very little sea-drift. Sea-drift is available for plants on the shore first; those inland receive very little, and a great deal of the beach lies away from the sea. That is one side of the problem: an insufficient supply of humus available from the sea. Moreover, I think that Dungeness does not even get its fair share of sea-drift on the foreshore, let alone inland, so that there is little material on which plants can grow. Thus one of its outstanding features is sterility. I thought the degree of sterility might help us, as the older portions would be most sterile, but this seems to be due not so much to greater age as to the prevailing wind from the south-west. On many of the beaches the western side is more sterile than the eastern, since material is drifting from the south-west to the often more sheltered eastern side. The oldest beaches are most barren, but they are also most westerly. The landward areas are also often sterile, which is to be expected, but does not help to date the ridges. The densest vegetation on the shingle is near Dungeness point, where favourable humidity and pebble size encourage colonization by plants.

An interesting feature is the number of sizable bushes, especially in that remarkable feature of the older maps, the Holmstone Wood, now represented by scattered holly bushes 6–8 feet high, some being 10–15 feet across. Often they are complexes of about half a dozen bushes apparently forming one. From Colonel Behrens' examination they appear to be 80 years old or so, perhaps regenerating from seed. We may obtain further information from the holly bush areas in the future, especially if profile excavation of the underground system is possible.

Ground vegetation is established on peaty material, lying in thin discontinuous strips over the shingle. This is called "mor", raw heath humus composed of the debris of *Calluna*, the ling or heather, and other plants, and drifted soil. It is a secondary wind-carried drift which lies in sheltered or moist places, to be temporarily stabilized by mosses and lichens which bind it compactly together. It may last a few months or many years, and then drift away. We hoped at first to detect what plants were in it, and perhaps take pollen profile records to see what it derived from and obtain some idea of its age. The Macaulay Institute for Soil Research, Aberdeen, reports the pollen of oak, birch and *Calluna*. On Dungeness there is only one extensive patch of ling, on the east side of Lydd Beach. A much larger patch near Lydd itself was burnt out about 1921, and is just coming on again as a result of Colonel Behrens' afforestation of Dungeness. He enclosed a large area of young forest trees to keep out rabbits, and the ling

has been growing quite well, for *Calluna* in much greater quantity may account for the enormous quantity of mor, and give another line on its age.

Vegetation follows the crest contours of the shingle ridges, as is strikingly shown on the air photographs. Though there are differences, these are not clearly associated with the age of the beaches.

Mr. GORDON MANLEY: The authors have opened up another possible line of approach to the question of the earlier climate of Great Britain. It seems to me that the diagram of ridge heights (see Fig. 2) might be dated by historic storms. The greatest storm which ever damaged the British Isles was on November 26–27, 1703. The outstanding ridge between 1600 and 1800 might be the result of this storm. There was a great storm in 1668; and great inundations due to storm on the coast of Lancashire in 1553. There is evidence from the coast of Wales that much subsidence took place after the Roman period, probably about the 6th century. A great storm assigned to 543 did much damage on the coast of Wales.

What would be the effect on beach growth at Dungeness of a run of easterly gales such as affected, they say, the English Channel early in the 17th century?

Mr. D. P. BRACHI (The Aircraft Operating Company, Ltd.): I have seen a storm, by no means abnormal, coming at the beginning of the spring high tides, which held the water up so that there was no normal low tide; for a day the sea scarcely retreated at all, and the second high tide caused an additional rise. Such a piling up of water may account for the abnormal height of the Chesil Beach.

I hope that the air survey of Dungeness will be completed and the mosaic may reveal features of Dungeness which are not visible even on Mr. Lewis' profiles and plans.

Mr. A. R. HINKS: Lieut.-Colonel Tankred Behrens was my friend for more than thirty years, and I shall be glad if I may say one word of thankfulness that the scientific work which he took upon himself to do at Dungeness fell, when he was attacked with a grave illness which rapidly proved fatal, into the hands of Mr. Lewis to preserve and to bring eventually to fruition. We understand that much of it was based upon the Air Survey he instigated, which cannot in present circumstances be published. Mr. Lewis has had to speak to-day of past levels at Dungeness rather than of recent happenings. Nevertheless, a great deal of the work Tankred Behrens did, if it has to remain unpublished for a time, is, his friends are thankful to know, in safe hands.

Colonel Behrens was a man of great versatility. He had many duties to perform in the course of his career as an officer of the Royal Engineers; and to each of those duties, which might have been done in the conventional way, he brought some touch of originality. There is in the Society's Museum a model of the special boundary pillar, worthy of its historic place, which he saw to erecting upon the Brenner Pass when he was British Commissioner for the Austro-Italian Boundary. When his work was that of Garrison Engineer at Shorncliffe, and he had to do a certain amount of planting, he said to himself: Why should we not plant cricket-bat willows in order to make in time this official property of extra value? These are two slight examples of the imaginative turn which his very charming mind used to take. I can well understand how much Colonel Behrens' fertile brain contributed to the most interesting research that Mr. Lewis and his friends have carried out.

The following three written contributions to the discussion were submitted to Mr. Lewis by the Editor, and are considered in his reply.

Dr. CHAPMAN: Mr. Lewis' work, with the data that emerged during the discussion on coastal changes held here a year ago,[1] is resulting in the development of a general picture similar to that built up by Dr. Godwin and his co-workers for the Fenland. The problem of coastal movement is perhaps more difficult of approach because the data are less susceptible to quantitative work.

Dr. Godwin has recently [2] produced evidence suggesting a continual rise in sea level since about A.D. 500, whilst Mr. Lewis suggests that the rise did not take place until about the fifteenth century. A discrepancy of 900 years is too large to be disregarded. I doubt whether, at the moment, we have any evidence to enable us to solve this problem, but if the pictures presented by Dr. Godwin and Mr. Lewis are to be fitted together, we must try and find a solution. There is one feature of Mr. Lewis's results that I believe demands further study. He postulates a change in level of 5 feet in the last 500 years, and a further change of 5 feet in the opposite direction during the preceding 200 years. In other words, movement was rapid between the thirteenth and fifteenth centuries, and slower afterwards, the former changes taking place at about two and a half feet per century. One would have thought that such changes would have become evident in historical records, and I would like to ask Mr. Lewis whether he has any data on this point.

A year ago I pointed out that data could perhaps be obtained from a study of silt deposition and rate of salt marsh growth, and I would like to suggest to Mr. Lewis that a study of the soil depth on the Cuckmere marshes might provide further data. At the risk of rendering the problem still more complex I would emphasize my belief that we have just concluded a period of relative coastal stability during which the present Scolt Marshes were formed, but that the depth of mud in the older landward marshes indicates formation during a period of subsidence. I also believe that recent events in East Anglia are indications of a fresh fall in land level in relation to the sea, but that it has only gathered way to any degree within the last few years. I do not believe, for example, that Holme marsh in Norfolk could have reached maturity in 60 years as Mr. Steers has shown [3] unless the coast had been relatively stable. On the other hand, I am aware that the axis of movement is usually placed around the Humber–Mersey line, and therefore Norfolk would not be affected to the same extent as the more distant south coast.

Finally, I suggest that we need to know more about the effect of "inning" marshes. I am not convinced that changes of level observed after many years of enclosure are wholly due to changes of land level relative to the sea. I believe that some of the change is due to settling of the silt through improved drainage. What we need is for a new area to be inned and accurate measurements of levels to be made at the time and during the succeeding years. There is little doubt, I think, that inning the Bay of Fundy marshes in Nova Scotia has resulted in a lowering of the marsh surface due to settling of the silt, but here also, unfortunately, no figures are available.

Dr. GORDON WARD: Speaking only as an antiquary, and not as a geographer, I should nevertheless like to make it clear that the historians of Romney Marsh cannot fulfil their task without first giving close attention to the conclusions of geographers such as Messrs. Lewis and Balchin. This is true also of those who

[1] *Geogr. J.* 93 (1939) 399, 491.
[2] *Phil. Trans.* Ser. 13, 1940, vol. 230, p. 239.
[3] *Geogr. J.* 87 (1936) 35.

study the adjacent coast-lines of Kent and of Sussex. All such study has long been obscured by the tacit assumption that the sea level in Roman times stood where it does to-day, or even that it was lower in Cæsar's day than it has been since. It has frequently been stated that the Rhee Wall which divides Romney Marsh is a Roman work made to reclaim the northern part of the marsh from the sea. Even the authors of to-night's paper are not prepared to give final judgment on this point, although to accept this wall as a work of the first or second century A.D. appears to be disastrous to their conclusions.

At this point an antiquary may perhaps offer assistance. The earlier maps of this area, particularly a sixteenth-century manuscript map at New Romney, show that there were originally two walls between which ran a waterway which, from its straightness, was surely artificial. There are many records of this channel and of the difficulty of keeping it clear. There are also records, given in Dugdale's 'Imbanking,' which appear to refer to the digging of it, although until certain place-names can be identified the exact meaning of these records remains not altogether free from doubt. A double sea wall enclosing a waterway is sufficiently remarkable to arouse suspicion. Those who are content to reject the Roman hypothesis may point to a commission appointed by the King in 1324 to enquire into the damages caused by "a certain trench made betwixt Apeldre and the port of Romenale" (Dugdale, p. 29) as evidence of the approximate date of the making of the Rhee channel. The double wall no doubt originated at the same time from the earth thrown out by the diggers, and was increased in size thereafter by the perpetual attempts to keep the channel clean. The advocates of a Roman origin refuse to interest themselves in such records, but those whose minds are still open may care to hear the evidence of what the marsh looked like in Saxon times. If the wall was Roman we ought at least to find that the land on the seaward side of it should be in some way distinguished from that to the north. It might well be flooded at high tide. It should at least be marsh and not good arable land. We find in the Saxon charters no difference at all. No wall is ever mentioned. Even the very oldest place-names, those which end in *-ham*, are scattered impartially on either side of the line of the wall. The line of a river or estuary running from Romney towards Appledore is mentioned as the Rumenea in 895, and as the Genlida in 830. But it does not approach the Rhee Wall. It encloses a large area south of the wall in which are the named settlements of Floteham (Fairfield), Misleham and Broc (in Brookland), and Betlinghope. To this we may add that there is ample evidence of the northern branch of the Limen (later called the Rother), which must have run right through the wall, if it were there at the time, to reach its outlet below Lympne. These are some brief indications of the case against the Roman origin of the Rhee Wall, but, since the evidence of Roman origin is only a wearisome reiteration of the alleged fact, they merit considerable attention.

Mr. J. A. Steers: Mr. Lewis has given to those interested in shore features a very provocative paper. He has also wisely pointed out that by its very nature it is largely hypothetical, and while this does not minimize either its interest or value, it implies that to prove his views he must check them by other lines of evidence. Recent changes of level there certainly have been, but there is a danger that because they have been recognized by surer or positive evidence elsewhere, they may be recognized in Dungeness, not by similar evidence, but by the varying heights of such fickle structures as shingle ridges. It does not follow that, because certain changes have been demonstrated in the Fenland, they should be also found at Dungeness. Mr. Lewis notes this, but at the same time the closeness of the agreement that he finds between his ridge heights and the assumed movements of sea-level relative to the land in that area and the Fens

makes the sceptic wonder if that agreement is not too good. Moreover, although a plausible case has been made out for the dating of the ridges, there is nothing approaching certainty in the claim that various groups of ridges were built at definite periods. It may be that the long ridge system through Lydd just post-dates the 25-foot submergence: there is no proof of it. Whilst I agree that if a certain group of ridges is of similar height throughout, but higher or lower than a neighbouring group, there is the possibility that it was formed at a different level of the sea, I also feel that that argument does not give sufficient weight to the supply of shingle available at the time and to the particular conditions acting upon the group. Furthermore, there is always the tendency for old ridges to become flatter in course of time, and it is worth while considering if they may not have settled to some extent.

The thirteenth and fourteenth centuries were periods of greater storminess than usual. Further evidence in parts of England also suggests that the sea-level may have been higher. But even if sea-level were higher at Dungeness, it is at least possible that shore ridges were more influenced by the storms than by a small change of level. The environments of Dungeness and the Thames Estuary and the Fenland are not comparable. I do not put this forward as an argument against Mr. Lewis' views, but rather as a warning against not envisaging other possibilities besides changes of level. In the Fenland quiet conditions of sedimentation and peat growth succeeded one another: Dungeness, by its very nature, was always in the zone of powerful wave action. Furthermore, on an open shoreline it is often extremely easy to pick out erosion forms at slightly different levels, but it is far more difficult to show that they were formed when the sea stood at corresponding levels. If those levels were comprised within the same range as that postulated for the Dungeness ridges I would go so far as to say that on an open and exposed shore it would be impossible to discriminate between them on height alone. The argument applies even more strongly to constructed features, which are notoriously haphazard in their disposition as may be seen by the heights to which shingle is thrown up along our exposed western shores to-day. It may be argued that a coastal foreland of the Dungeness type is different in this respect because, as Mr. Lewis rightly says, so many ridges of any group are consistent in height. I do not however think that this, or a similar view, is a convincing argument, judging from examples I have seen in these islands and elsewhere.

If I interpret Mr. Lewis correctly the sea-level is presumed to have risen *c.* 5 feet since the fifteenth century; in the thirteenth century it was near the present level; in the eighth century it was one or two feet lower, and 5–6 feet lower in Roman times. This implies a total movement of 5 or 6 feet. Suppose it were 5 feet: what would happen if sea-level were now to rise 5 feet? It would presumably mean H.W.M. of spring tides would be some 5 feet above the present, and one wonders just how the ridges that would then be formed could be related to those now existing. Much would depend on the rate of the change, and I should like to ask Mr. Lewis what he thinks would happen. If the change took place in a short time I should imagine that there would be a good deal of erosion of the lower ridges. When we are able to see the detailed air-mosaic this point may be made clear, but on the present evidence I do not think enough has been allowed for it. As far as I can visualize it, the presumed sequence of events indicates slow changes of level, but even then I should have thought that with a rise of sea-level there would have been some noticeable erosion and truncation of ridges. The final answer must be sought in a careful analysis of bores put down in and around Romney marsh much as has been done by Dr. Godwin in the Fenland. Even then I think it will not be too easy to connect with any degree of

finality changes of level that may then be exemplified with differences of ridge height.

I do not wish these criticisms, for what they are worth, to be taken as meaning that I rule Mr. Lewis' views out of court. Mr. Lewis has enthusiastically outlined a possible new line of evidence, and one which, if proved, is of considerable value. My own instincts make me chary of accepting it despite its obvious attractions, but I am grateful to Mr. Lewis for describing it so clearly and interestingly.

Mr. W. V. Lewis: Many important points have been raised. The first relates to a car sinking in new shingle but not in old, which is probably due to sand or dust between the pebbles consolidating old shingle; vegetation does the same irrespective of the age of the shingle. Dr. Dudley Stamp asked how ridges are built, and why new ones are formed afterwards. As I have considered these points elsewhere [1] they were omitted from the present discussion. Ridges are built whenever more shingle is supplied to an open foreshore than is removed. On the eastern shore of Dungeness this deposition is due to the weakening of the prevalent south-westerly waves as they round the Ness and travel, as very obliquely impinging waves, along the eastern shore. Rate of building naturally varies, but five to ten years per ridge is an average, and the distance between crests is about 20 yards. There is no mystery about the action of waves in throwing up ridges: the processes can be examined in the glass-sided wave trough at the Department of Geography, Cambridge. The usual estimates of chalk cliff recession [2] suggest a widening of the Straits of Dover of less than half a mile in the last thousand years, which would hardly affect wave size at Dungeness. Old ridges have been lowered by settling and this must be allowed for. Trough depths depend almost entirely on the distance apart of the ridges and so cannot be relied on to indicate past sea levels.

Mr. Jolly suggests that a fluctuating change of sea level is more likely than a uniform one; evidence of this might well exist in the ridge heights, but at present it cannot be disentangled from variability due to storms, etc. Mr. Pearl's reference to the botanical work is most welcome, as also is his tribute to the generous assistance Colonel Behrens gave us all at Dungeness. Mr. Manley's knowledge of historic storms might well assist in dating the ridges, and the storm of 1703 might have built the exceptionally high ridge about halfway between the ? 1600 and 1800 shores. Storms can, as Mr. Brachi suggests, hold up the water level, as shown at Horsey. Records of the 1287 inundation describe how the tide appeared to rise twice without ebbing. Dr. Chapman considers our findings are too different from those of Dr. Godwin in the Fenland, whereas Mr. Steers considers that they are too similar. The chief difference is that we seem to have evidence of an oscillation about the thirteenth century which is absent in Dr. Godwin's results. As post-Roman movements in the lower Thames area seem to differ both from the Fenland and Dungeness, one must not expect exact agreement between changes at the two latter places. We agree with Dr. Chapman that information is required on the effect of inning on land levels.

Dr. Gordon Ward's reference to the historians of Romney Marsh requiring to pay attention to the findings of geographers applies with equal force the other way round. Dr. Gordon Ward has already contributed much towards the solution of our problems at Dungeness, and the convincing evidence of the post-Saxon age of the Rhee Wall given both in this discussion and in maps he has since shown the authors, suggests that his contribution is by no means exhausted.

[1] *Geogr. J.* 78 (1931) 131; 80 (1932) 322; *Proc. Geol. Assoc.* 49 (1938) 109.
[2] W. H. Wheeler, 'The sea coast,' p. 200.

Mr. Steers introduces a note of healthy scepticism and the authors already owe much to his criticisms of the paper before it reached its present form. His statement that " recent changes of sea level . . . have been recognized by surer or positive evidence elsewhere," does not apply to the last 1500 years or so, the period with which we are mainly concerned. Extremely little is known about the relative positions of land and sea in post-Roman times, and this was one of our main reasons for writing the paper. We agree with Mr. Steers that erosion forms only 5 or 6 feet apart vertically would mean little on an open coast, but do not agree that this argument applies even more strongly to the constructed features with which we are dealing, because the height that these ridges are built to-day can be examined along a continuous front of over 8 miles. We have levelled 3½ miles of these shore ridges and find that a variation of more than 1 foot on either side of the mean is rare, unless other clearly recognizable features such as bends or breaches are present. If the sea level rose suddenly 5 feet, new ridges would presumably be thrown back over the present ones and there would be some initial erosion. Subsequent ridges would probably average 5 feet higher than those built before the rise, and the plan of the ridges would indicate something of the course of events. This appears to have happened once at Dungeness, in the ridges estimated to have been built in Roman times.

The disturbing influence of exceptional storms is clearly indicated in the ridge heights, superimposed on long period changes, and we have drawn attention to other possible disturbing factors. In putting forward our interpretations of the slow but persistent changes of ridge heights, we follow the traditions of the Geological Survey and put what appears to be the simplest interpretation of the known facts; we make no claim for finality.

The CHAIRMAN: I thought at first that this might prove a dry subject, but instead of having one paper we have had a well-balanced symposium. All that remains for me to do is to offer our thanks to Mr. Lewis, and others who have spoken, for the instructive afternoon they have given us.

INTERNATIONAL BOUNDARY PROBLEMS

INTERNATIONAL BOUNDARIES; a study of boundary functions and problems. By S. WHITTEMORE BOGGS. *New York: Columbia University Press*, 1940. 9×6 *inches;* xviii+272 *pages; illustrations and sketch-maps.* $3.25

THIS book, by the Geographer to the United States Department of State, is based in great part on a course of lectures delivered at Columbia University in the summer session of 1939, and loses something by an implied necessity to arrange the subject academically, to schedule and classify the functions of boundaries, to find an index for the Compartmentization and consequent "interruption factor or nuisance effect." This search for first principles leads away from what Lord Curzon called "the incomparable drama" of the subject, and cannot afford a glance at its comedy.

At an early stage the author tabulates for each continent except Australia (which has none) the miles of international boundary per thousand square miles of area, and finds that the figures, ranging from 1·1 for North America to 4·0 for Europe, seem to be a fairly satisfactory index of the extent to which the continents are divided into compartments. He then multiplies the first index by the population per square mile and obtains a second index, ranging from 27 for North America to 480 for Europe; but concludes that neither index corresponds with boundary actualities. Something between the two, he thinks, might be a better index of the relative complexity of boundary situations by continents to-day, but admits that the manner in which boundaries operate is more important than their mere extent: he has however no formula to propose, and one may think that the incalculable factor of politics makes any numerical index illusory.

To consider more closely this attempt to calculate an index, let us look at the figures for the continent of North America, in which he includes Central America down to the eastern boundary of Panama. Mr. Boggs gives in his Appendix A the lengths of the international boundary segments but not the areas or the population which he has assumed. The United States–Canada boundary is 4001 miles long according to Appendix 2, p. 25, and 3987 according to Table 2, p. 40; of the latter 2198 miles are water. Thirty million people, or a million people thirty times, cross from Canada into the United States in a year, of which $6\frac{3}{4}$ million in nearly a million cars pass through the border city of Windsor, Ontario, and another thousand a day are merely cutting across Canada in the express from Buffalo to Detroit. Twenty-three million people cross yearly from Mexico to the United States over the 1905-mile boundary of which the Rio Grande forms two-thirds, from the Atlantic to the twin cities El Paso (Texas)–Ciudad Juárez (Chihuahua). Mr. Boggs' Fig. 8 and Plate II show how troublesome here a meandering river boundary can be in a flood plain well populated and cultivated, and describes the manifold duties of the International Boundary Commission with its duplicate offices in the two cities. Its recent rectification of the channel downstream from these cities reduced the length of the section from 155 to 86 miles. While at Windsor the nuisance value of the boundary is the delay caused by the slightest control of the great trans-border traffic, at El Paso it is (or was) that, when the river every few years jumped sideways a mile or two, it left subjects and property of one state stranded in the other. The trouble in thousands of miles of boundary tends to be concentrated at a few points, and their number rather than the whole boundary length may be important factors in the index sought.

Contrast these two boundaries of the United States with the 1541-mile boundary between Alaska and Canada, crossed by two routes only, the railway

from Skagway to Whitehorse, and the river Yukon giving access to Dawson and the Klondike: between Alaska with 586,000 square miles and 59,000 people, and Yukon with 207,000 square miles and perhaps 4000 people. Or consider the 1476-mile boundary between Labrador and Quebec, mostly unsurveyed, position in most places quite undetermined, crossed if at all by a few hunters.

And now consider the small states of Central America which Mr. Boggs includes with the larger states and territories of the North. Their boundaries with Mexico and with one another come to 2339 miles: their area is only 146,000 square miles. For this group alone the index of the first formula is 16·0: very high, yet we may doubt if their international boundaries give twelve times as much trouble as those of North America as a whole. We permit ourselves then to share the author's doubt whether these index figures, functions of boundary-length, area, and population, have any validity: equally important but less readily enumerated variables have been excluded from the formula.

An interesting chapter on the principles of water-boundaries, not rivers, but great lakes and arms of the sea, is taken with some changes in footnotes and illustrations from a paper in the *Geographical Review* for July 1937, with Lake Erie as an example. The treaties of 1783 and 1814 had placed the boundary in "the middle" of the lake. The International Waterways Commission, reporting at Toronto in 1907, considered that this might be defined as A, a line at all points equally distant from each shore, or B, a line following the general lines of the shores and dividing the water area into two equal parts, or C, a line along the mid-channel dividing the navigable portion of the lake, and at all points equally distant from the shoal water on each side. Solution C is inapplicable to Lake Erie and to any lake which has no particular deep-water channel. Solution B seems to be that adopted by the Commissioners, though Mr. Boggs does not say so; the international water-boundary is, except among the islands at the west end, a set of four straight lines, dividing the 10,000 square miles of the lake as nearly as need be into two equal halves. Solution A seems to have been misunderstood: the interpretation of it given by the author in his Fig. 21 is, as he concludes, absurd, and he puts forward a solution D which appears to us no different from the real intention of A; it is complicated and makes the boundary wander in a vague way, not even dividing the lake equally. It would have been interesting to be told what is the practical need for a boundary in the Great Lakes: to preserve fishing rights, or control smuggling, or what? The steamship route from Buffalo to Detroit is mostly in Canadian waters.

The author then considers how a land-boundary should be continued through territorial waters to the high seas, and we think rightly disagrees with the solutions of Lapradelle. The boundary of territorial waters is made from a series of intersecting arcs of three nautical miles radius, struck from each projection of the coast, but this scalloped line, made up of arcs, is not properly called an envelope; where the arcs struck from promontories adjacent to the boundary intersect is the common point of the two water-boundaries, and this has to be joined to a point where the land-boundary reaches the coast, by a straight line if no islands interfere. The line may be more than three nautical miles if the land-boundary end is set back in the coast-line, but it should never be less, as it is by some mistaken definition on the Canal Zone boundary in the Bay of Panama. An interesting exception is where the land-boundary is a river with a channel continued in the sea-bed. In that case, says Lapradelle very reasonably, the boundary out to sea may well follow the centre of the navigable channel.

On the classification and terminology of boundaries Mr. Boggs is careful to distinguish as usual between boundary lines and frontier regions, but quarrels

with the term "natural boundary," partly because it may not seem natural to the people who live there, and because Lapradelle says that natural are no more than "derived artificial boundaries," Fawcett and Sölch complicate the terminology by calling them natural barrier frontiers, and Hartshorne by subdivision into different kinds. So Mr. Boggs resolves not to use the term in any strict sense, and suggests a more comprehensive classification by Physical, Geometrical, Anthropogeographic, and Complex types. An unexpected member of the first is the contour, used in the boundaries of the Canal Zone. He then considers a Genetic Classification of Boundaries, involving Hartshorne's terminology of *antecedent* when they antedate the cultural landscape; *subsequent* when they do not; *superimposed* when they do not conform to it; and *consequent* when they are drawn through uninhabited regions. Upon the need of such terminology one may have different opinions: it is too apt to become a jargon, as did the same or very similar terms in physiography. On the British distinction between delimitation and demarcation, so much obscured by the French, the author is firm, and British geographers may be glad to have his reference to an address to the Royal Society of Arts on 6 November 1935 by Colonel Sir Henry McMahon, who there tells how he found the need for distinguishing between the definition of the boundary by agreement in words and by marks on the ground, found two words delimitation and demarcation given the same meaning in his dictionary, and in a lecture at Woolwich about 1897 proposed for them the distinct meanings which they now bear.

One may regret that the technique of delimitation and demarcation is little considered by the author. He refers to astronomic lines determined by astronomic and geodetic observations and calls them straight, but does not remark that if a meridian or parallel is specified in an agreement, one should say also to what initial astronomical point or to what system of geodetic triangulation it may be referred. Because latitudes were determined independently at various points on the 49th parallel boundary, with strong local deviations of the vertical, there were in one district three parallel vistas cut and two lines of monuments left, with nothing to tell which line was accepted, because the reports of both commissions were lost. Mr. Boggs does not mention the exploit or discuss the morality of interfering with the *divortium aquarum* by diverting a river from the Pacific to the Atlantic (Argentine–Chile boundary); he avoids the definition of *coast*; the question whether it is the same as *shore*; whether it extends up all inlets however deep; whether the coast and the sinuosities of the coast are the same thing; whether a line parallel to the coast runs round the heads of all inlets; whether the ocean extends to the coast; and whether the glacier front of an ice-filled inlet is coast: all of which questions gave desperate trouble to the Alaskan boundary commissioners.

Since Mr. Boggs has treated the Canada–Labrador boundary as international one must regret that he has not discussed the most interesting judgment of the Privy Council's Judicial Committee in 1927, by which the Coasts of Labrador were held to extend to the watershed; the river of St. John's, clearly identified in the Order-in-Council of 1763 by reference to Anticosti and so shown on Roque's map of the same year and on official Canadian maps until 1926, was declared to be the Romaine, a much larger and more recently named river farther east; and the boundary is to go from the unlocated head of the latter to the "crest" of the unexplored St. Lawrence–Atlantic watershed on a recently glaciated plateau where lakes discharge impartially from either end. There is also a very important decision of the Privy Council in the case of South Australia and Victoria, that a meridian boundary once marked and proclaimed must stand, though it was wrongly determined, not by bad work of the surveyors but through error in

the adopted longitude of Sydney, before the days of radio-signals or even cables. This was indeed an inter-state boundary, but the arguments of the Judicial Committee are equally applicable to one international.

No book can cover the whole ground, and to say that this one rather neglects what a reviewer has always found the most interesting side of the subject is no discourtesy to it. Students will find in it very much of importance, will be directed to a wide range of authorities, introduced to attractive and often unfamiliar paths of inquiry, and stimulated by its bold generalizations. They will regret only that the maps are not of the same high quality as the print and the illustrations. A. R. H.

REVIEWS

EUROPE

I BOUGHT A MOUNTAIN. By THOMAS FIRBANK. *London: George G. Harrap and Co.*, 1940. 9 × 5½ *inches;* 320 *pages.* 8*s* 6*d*

In this book the author records the results of a field excursion which has gone on for nine years and is still continuing. With a capital of £5000 Mr. Firbank, in the early winter of 1931, bought a farm whose sheep-walks covered the southern flanks of the Gliders, in the Snowdon district. In a pleasant and intimate exposition we are introduced to the mysteries of sheep breeding and farming on an upland farm where success or failure depends entirely on sheep. Three altitudinal divisions of the farm are recognized—the unfenced mountain pastures, the enclosed "fridd" pastures below the mountain wall but above the farm buildings, and the rich meadow pastures of the river valley cut each year for hay. To these must be added a fourth, in this case the lowland pastures of the Conway valley to which the ewe lambs of Dyffryn Farm are sent for fattening and wintering in their first year, after which they are hardy enough to face the rigours of the mountain pastures at all seasons.

Those who believe that the economic geographer's education is incomplete unless a knowledge of industrial and manufacturing processes is included, will learn from this book the fine adjustments, the experiments, and the changing problems which confront the sheep farmer season by season and from year to year. Intimacy with nature breeds human sympathy and understanding, cooperation, and mutual aid, and nowhere are these attributes more strongly marked than amongst the animal breeders of mountainous districts.

There are descriptions of incidental and, at times, incongruous events, such as the snack-bar interlude, the record run up and down the fourteen "three thousand feet and over" peaks of the Snowdon district, pig breeding, poultry keeping, and an experiment in hydro-electrification. In many ways this is a delightful book to read and digest, although its economic and political views may be somewhat coloured, for Mr. Firbank started his farming education with the sum of £5000. D. T. W.

WHERE THE RIVER SHANNON FLOWS. By RICHARD HAYWARD. *London: George G. Harrap and Co.*, 1940. 9 × 5½ *inches;* 328 *pages; illustrations and sketch-map.* 12*s* 6*d*

Mr. Hayward has written an agreeable book on an area of Ireland which, once remote, has in recent years been the scene of developments important not only to Eire but to Western Europe. In recounting his journey down the Shannon he blends attractively legendary and historical incident, place-name lore, and reports on modern progress—the hydro-electric station at Ardnacrusha, with the part played in its conception and execution by Dr. T. A. McLaughlin, the reviving activity on the Grand Canal, Radio Eireann at Athlone, and the trans-Atlantic air port in the Shannon estuary. The Foynes air port is temporary, and will be replaced by the ambitious sea and land base at Rineanna to the east, upon which work has been begun. Mr. Hayward writes throughout with high spirits and much enthusiasm; his statements should not always be accepted without examination: proof for instance that Turlogh O'Carolan was the composer of the "Star Spangled Banner" is not forthcoming. However the prime object of the book is to entertain, and this it achieves. The illustrations are excellent, particularly those of specimens of Irish Romanesque architecture, in which the Shannon valley abounds. G. R. C.

HIGHLAND VIEW. By JAMES BRAMWELL. *London: Robert Hale*, 1940. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches;* 230 *pages.* 8*s* 6*d*

This is a pleasant book about one of the less well-known districts of Scotland. It is made up of random memories of visits to Argyll from Crinan to Kintyre and the islands of Jura and Islay, of old tales told by men and women of the country, and sketches of these men and women themselves. The scenes have the sharpness and delicacy of outline characteristic of this part of West Argyll and the people recall chance acquaintances met on quiet roads and on board gallant little boats, but the book cannot be said to be a serious contribution to geography, although the geographer who knows the country can, as he reads, provide landscape and people with their true geographical setting, and to those who do not know western Argyll it might be a rather charming invitation to visit it. G. M.

ASIA

CULTURAL RELATIONS ON THE KANSU–TIBETAN BORDER. By ROBERT B. EKVALL. (University of Chicago. Publns. Anthropology. Occasional Papers, No. 1.) *Chicago: Univ. Press* (*London: Cambridge University Press*), 1939; $9\frac{1}{2} \times 6\frac{1}{2}$ *inches;* xiv+88 *pages; map.* 7*s* 6*d*

The theme of Mr. Ekvall's monograph is the cultural inter-relation between the four peoples who inhabit the remote region of the Chinese north-west frontier: the Chinese settlers, the Tungans or Chinese Moslems, and the nomadic and the sedentary Tibetans. Mr. Ekvall, a missionary and the son of missionaries, was born in this region and has spent most of his life there. He speaks not only Chinese but the various dialects of Tibetan used on this frontier, and has thus an admirable equipment for the task he has undertaken. His duties as a missionary brought him into close contact with the daily life of the Chinese villages, both Moslem and Buddhist, while inclination and the exigencies of civil war made him a not unwelcome guest in the camps of Tibetan nomads. No one perhaps has had a better opportunity of penetrating and expounding the true relation which subsists, in this part of the world, between the desert and the sown.

This relationship is not determined by race so much as by economic needs and rivalries. Between the two branches of the Chinese-speaking community, closely related by language and by blood, there exists a bitter smouldering hostility which has not infrequently flared up into savage and merciless warfare. Between the Moslem farmers and the nomadic Tibetans, on the other hand, there are many bonds of friendship and trade, although no two peoples could differ more in race, language, manner of life, and, above all, religion. Mr. Ekvall shows that the religious animosity between the Moslems and the Buddhist Chinese is the excuse and not the cause of their hostility, for the fanatical Tungan who professes such detestation for the "pagan" Chinese is on terms of intimate friendship with the equally pagan Tibetan nomad. The real causes both of hostility and friendships are shown to be economic. The two Chinese communities are rivals for the inadequate areas of land fit for cultivation, and this rivalry is rendered more acute by the greater fertility of the Buddhist Chinese, and the greater pugnacity of the Moslems. Equally, between the Moslems and the nomad Tibetans the link is trade. The nomad must trade to get grain, which he cannot produce on the high steppes, and the Moslems, here as elsewhere in China keen merchants as well as farmers, buy skins and furs from the nomads for the markets of eastern China. Between the Chinese and the sedentary Tibetans there is not the acute rivalry found between Moslem and Buddhist Chinese, although both here are also farming communities. The

Chinese indeed are gradually ousting and absorbing the sedentary Tibetans, a process which can also be observed in a more advanced stage on another part of the Sino–Tibetan border, North Yunnan. But this slow infiltration does not seem to be greatly resented by the Tibetan farmers, partly because they themselves all aspire to leave the land and return to the nomadic life, which to them is greatly superior and enjoys among them a far higher prestige.

It is to be hoped that Mr. Ekvall will develop this interesting theme in a full-length book, enriched by his almost unique experience of this isolated region where culture contacts may be observed free from the complicating factor of European influence. C. P. F.

A CAVALIER IN CHINA. By A. W. S. WINGATE. *London: Grayson and Grayson*, 1940. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches; 328 pages; end-paper sketch-map.* 15*s*

Colonel Wingate, who died last year, was well known in India, but this Chinese episode in his career may come as a surprise to many. One can well understand his widow feeling that this account, worked up later from careful notes made at the time, would give a picture of a gallant, light-hearted gentleman, and at the same time be a tribute to the people whom he came to like so much. The tribute has particular point, because Wingate travelled from the central Yangtze to Burma in 1898, at a time when relations between England and China were far from good. The Chinese were working up for the Boxer outbreak of 1900, and Hunan Province was supposed to be the most fiercely anti-foreign part of China. Yet this courteous, friendly Englishman was able to go right through the province and suffer nothing worse than obstreperous curiosity. What Wingate apparently did not know was that one of the Reformers, Tan Tzu-tung, had a year or two before begun to persuade his fellow scholars in the province that there was more in Western civilization than they had supposed; and the tide of misunderstanding was already on the turn. Further, Wingate took the trouble to learn as much Chinese as he could.

The editors have done right in preserving the zest and naïvety of the original youthful notes. The value of the book to the historian is slight, and if it were not so plainly in the category of a pleasant account of a much-enjoyed journey, it would be open to strictures on the point of accuracy. Thus it is wide of the mark to speak of kuan-hua (officials' language) as "introduced many thousands of years ago," and what is the meaning of the Mongols "conquered by Buddhism"? The account of the acquisition of Wei-hai-wei is misleading, while the theory about Marquis Ito hurrying to Peking to give information to the Dowager Empress about anti-dynastic plans of the Reformers is, I feel confident, pure speculation. The curious thing is that young Wingate had an interview with Yuan Shih-kai and was much impressed with him, apparently unaware both then and later that he was the man who sold the pass against the Reformers. K'ang Yiu-wei never cherished anti-dynastic plans.

Apart from these mistakes the book makes good reading. The first part of it takes us back to pre-Boxer Peking. Colonel Wingate saw all that there was to see, and he had not only the power of observation but also the gift of frank, unaffected writing. E. R. H.

POLAR REGIONS

UNSOLVED MYSTERIES OF THE ARCTIC. By VILHJALMUR STEFANSSON, with a Foreword by STEPHEN LEACOCK. *London, Toronto: George G. Harrap and Co.*, 1939. $9 \times 5\frac{1}{2}$ *inches; 352 pages; maps.* 10*s* 6*d*

Mr. Stefansson's five Mysteries are of very different orders of interest, and make uneasy company in this book. Not one of the five is inexplicable on the known

facts, as a good mystery should be: it is merely a question which of two or more explanations is to be preferred, in the absence of conclusive evidence. The first is the Disappearance of the Greenland Colony. Towards the end of the tenth century Greenland was colonized from Iceland; by 990 the settlements were organized as a republic; in the year 1000 a bishopric was established; in 1261 the republic became a province of Norway; in 1279 Pope Nicholas III agreed that the Vatican had been hasty in excommunicating the Greenlanders for non-payment of tithe; in 1396 the Saracens demanded twelve Greenland falcons as ransom for a son of the Duke of Burgundy; about 1418 the settlements were ravaged by barbarians, said to be English privateers; the last recorded connection of the colony with Scandinavia was in 1448; but Paul Nørlund has shown that Europeans were living as such in 1520. They were exterminated by the Eskimo says one school; they died of deficiency diseases when European supplies were cut off says another; they were more sensible, thinks Mr. Stefansson, took to hunting and living on the country, throve on a meat diet of seal, intermarried with the Eskimo, and their descendants showed the proportion of attractive features and fair complexion that Hans Egede saw in 1721.

Much less interesting is the Strange Fate of Thomas Simpson, first recipient in 1839 of our Founder's Medal, an officer of the Hudson's Bay Company who aspired to fill by land-journeys the gaps in the North-West Passage that had not been covered by sea. In 1837 he closed the western, between Point Barrow and Return Reef. In 1838 and 1839 he nearly completed the eastern journey between Kent Peninsula and Boothia Felix. Being bound for England in 1840 he either killed himself after killing two of his party, or was murdered by others in retaliation. The author inclines to the latter theory, but in default of evidence has collected much detail of jealousy, intrigues, and meanness in others which seem irrelevant to this unnecessary resurrection of a sad story.

The third of the five "mysteries" is the problem "how Sir John Franklin and his party of more than a hundred contrived to die to the last man, apparently from hunger and malnutrition, in a district where several hundred Eskimo had been living for generations, bringing up their children, and taking care of their aged." There is no mystery in the matter: they had not learned how to live as the Eskimo do, and it seems unnecessary at this epoch for the sponsor of a Friendly Arctic to spend so much sarcasm upon the earlier experiences of Franklin in the Arctic, or on a certain inadaptability of naval training and discipline of the time.

Nearly a third of the book is given to the fourth chapter "How did Andrée die?" and a great part of it, a tedious description of gradual conversion to living on fresh bear and seal, is irrelevant to the answer, which is carbon-monoxide poisoning from a Primus stove. Whether the light, worn tent was sufficiently air proof to make this possible has been doubted; and the precise cause of death is not the real interest of the story, which Mr. Stefansson has idealized. He disregards the obscurities of the journey told so imperfectly in Andrée's own diary, and so frankly in part by Strindberg. (See review in *Geogr. J.* 77 (1931) 362.)

The last chapter is on the "Missing Soviet Flyers," Levanevsky and his four companions, who left Moscow on 12 August 1937 to fly non-stop to Fairbanks in Alaska and were last heard in a fading radio-message two hours after they had passed the Pole. One of the four engines had failed and ice was forming on the wings. For a whole year search expeditions took the air, without results: first Wilkins, Hollick-Kenyon, and others from the Arctic coasts of Alaska and the Canadian North-West, later a number of Russians from the other side of the Pole. An excellent map from the *National Geographical Magazine* is reproduced to show the former, and Mr. Stefansson insists upon the moral that flying over

the frozen Arctic is much safer than over the open sea. All this makes the most interesting part of the book. For once the author has no fault to find in his principal subject, and he is satisfied that if the Soviet party did make a safe landing they would know very well how to live; they may even yet appear to prove his thesis that the Arctic is essentially friendly, and that those who have died there did so mostly by their own fault, incapacity to learn, caste-prejudice against lending a hand; which may be partly true, but need not be so unkindly exploited so long after the event.

PHYSICAL AND BIOLOGICAL GEOGRAPHY

EROSIONAL TOPOGRAPHY AND EROSION: a mathematical treatment with application to geomorphology, soil science, agronomy and engineering, with tables. By JAMES M. LITTLE. *San Francisco: A. Carlisle and Co.*, 1940. 9×6 *inches;* 104 *pages; diagrams*

The title of this book, even as restricted by the sub-title, 'A mathematical treatment,' is rather misleading, especially to geomorphologists, in that running water only is considered. The author attempts to link up erosional geomorphology with hydraulics and hydrology. He develops mathematically an erosional rating formula for uniform slopes, and provides numerical tables for practical application by soil scientists and engineers.

Arbitrary simplification of the many variables is essential. Flow is treated as of "turbulent" type. For flow in channels tables are given that are applicable to those of rectangular cross sections. Trapezoidal cross sections are also considered and extension to gullies of varied form is envisaged when more is known of the "plunging or shooting" type of flow which obtains in such watercourses. Sheet run-off is dealt with fully for virgin conditions as a basis for consideration of changes due to cultivation. The latter are discussed qualitatively.

A chapter on erosional geomorphology is of general interest. In it the discussion of the rôle of mass movement of the superficial layers as producing modification of the theoretical profiles inferred for water erosion may not meet with general approval. It is argued that since the soil is formed in situ as a fairly uniform covering and does not accumulate greatly towards the foot of a slope, mass movement is not of more than secondary importance in levelling of topography and soil transportation. Mass movement however affects layers well below the top soil, and the latter develops from above downwards to keep pace with surface removal by erosion so that its uniformity cannot be considered to bear critically on the extent of mass movements.

In view of the catastrophic devastation caused by soil erosion, any addition to our knowledge that will assist its prevention and control is to be welcomed, and the author must be congratulated on a courageous contribution to the scientific study of this great problem. S. E. H.

DIE TROCKENSEEN DER ERDE: eine vergleichend-geographische Untersuchung zur Gewässerkunde der Trockengebiete. By FRITZ JAEGER. (Petermanns Mitt. Ergänzungsh. Nr. 236.) *Gotha: Justus Perthes*, 1939. 11×7½ *inches;* 160+16 *pages; maps and diagrams. M.*20

A pan or dry lake (vley, sebkha, playa, salar) is the inland lake of areas with arid climate, thus at times flooded with water, but usually dry. The size varies from a few hundred feet in diameter to 100 miles and more; the shape can also vary, though the normal pan is round. Jaeger gives a description of various types of pans, mainly dealing with South-West Africa, not only because it was here that he himself made his most important investigations, but because this region is the typical home of the pan.

Coastal pans, usually with salt but at times fresh water, are either occasionally in open communication with the sea or completely independent. Pans of the coastal slope (*Küstenabdachung*) are comparatively insignificant, whereas the most important pans occur in the interior and particularly in the Kalahari. In the Karst region south and south-east of the Etosha Pan, mainly consisting of limestone, dolomite, and other soluble rocks, most of the pans are morphologically dolinas, some of which are constantly filled with fresh water (Otjiko and Guina) and thus form normal lakes. Not only does the quantity of the water appear to change considerably, but also at times the chemical composition (Lake Gagua).

Whereas in the marginal regions of South-West Africa the actual bedrock is constantly apparent, the true heart of this territory is the Kalahari, the young Eolian deposits of which cover up all older rocks. This is the classical home of pans, first described by S. Passarge. Ignoring anything below 100 metres in diameter and cutting out the whole region north of the Okavongo and Zambezi, Jaeger gives a minimum of nine thousand pans for the Kalahari alone. The largest and most notorious are the Etosha Pan (northern part of South-West Africa and Makarikari Pan (Bechuanaland). Calcareous pans show an incrustation of tufa, whereas the sandpan contains loose sandy deposits, at times sandstone. A transition stage is formed in the southern and central Kalahari by sandy deposits containing calcareous concretions.

The second part of Jaeger's book deals with the dry lakes beyond South Africa. Whereas the pans are the norm in South-West Africa and the freshwater lake the exception, the occasional circular depressions without water, within the rift valley zone of East Africa, can only be regarded as an exception to the rule. Examples of pans are given from Somaliland, the Sudan, and Sahara. Outside Africa, regions of dry lakes are to be found mainly in Hungary, Iran, Central Australia, and North and South America. H. P. T. H.

THE WEATHER EYE: an irreverent discourse upon meteorological lore. By C. R. BENSTEAD. *London: Robert Hale*, 1940. 8 × 5 *inches; 288 pages; illustrations and diagrams.* 8*s* 6*d*

As a source of meteorological information this book excels in giving concise answers to questions likely to occur to the lay reader. One might, for instance, search through many popular works without finding it stated that the wealth of the polar regions in optical phenomena of the halo class is due to the presence of invisible ice crystals at all levels of the atmosphere. Nevertheless the treatment is uneven: thunderstorms are dealt with at length but little is said about snowfall, and hail is referred to exclusively in association with summer storms, the existence of soft winter hail being ignored. In view of the author's denunciations of slipshod language it is a little surprising to find a statement about the "great frost in May 1935" lasting from the twelfth to the nineteenth as though it were a period of continuous freezing day and night as in winter.

As indicated by the sub-title, this book is designed for entertainment as well as instruction, and it may be described as a satire on the general attitude of the public towards weather lore and particularly on the shortcomings and foibles of the official weather forecasters. The representations are never unfair and certainly amusing, and are likely to be enjoyed as much by the officials concerned as by others. The suggestion that the local London weather forecast would be rendered more reliable if the officials at the Air Ministry preparing the forecasts from synoptic charts, were occasionally to look out of the window, is much to the point. It might be objected that the practice of studying the local sky would give London a more accurate forecast than that available for other parts of the

country, but there seems no reason why the capital should not reap this incidental advantage. L. C. W. B.

ECONOMIC AND HISTORICAL GEOGRAPHY

SUEZ, PANAMA, ET LES ROUTES MARITIMES MONDIALES. By ANDRÉ SIEGFRIED. *Paris: Armand Colin*, 1940. 9×5½ *inches; 298 pages; sketch-maps and diagrams. Fr.38*

This is a detailed and careful study. Facts geographical, historical, political, biographical, financial, and commercial abound, but happily they are selected for their significance, and so employed that the resulting synthesis becomes clear and vivid. The author's artistry is as evident as ever; he is never merely informative. His work achieves topicality at a moment when the naval forces of the United States must be adjusted through Panama to meet varying demands in Pacific and Atlantic waters; and when an Egyptian might well be excused for apostrophizing the statue of de Lesseps in words here quoted, "Voila l'homme qui a fait tous nos malheurs." The Suez Canal is in Egypt but of the World.

The story of both canals has been told before. Quite recently H. J. Schofield's admirable study of Suez was published as a Penguin Special volume, and separate articles on the engineering works, financial results, traffic returns, etc., are available for the student who knows where to look; but no single volume deals so adequately with both canals. The geographer has learnt to expect much from M. Siegfried: though there is much in the present study which has no immediate reference to physical circumstances, yet when these become significant, he establishes the relationships between them and the human activities affected. He treats not only of the larger space relationships concerned, but shows himself well aware of less obvious physical factors. We may instance his mention of the reefs and winds of the Red Sea, of the traditional views as to the difference in sea-level between this sea and the Mediterranean, of the importance of the geological structure in the canal cuttings at Panama; while two all too brief descriptions, the one of Suez and Egypt as approached by air from the East, and the other of the country viewed in an air traverse from Bogotá to Panama, could hardly be bettered.

The first half of the book deals with Suez, the second with Panama. Initial chapters in each portion deal with the larger geographical aspects of the two isthmus and the history of transit projects, in the one case going back to Classical times and in the other to the Spanish conquests of the sixteenth century. Then, in each case, are treated the political intrigues and financial expedients which led ultimately to the success at Suez, and to the tragic failure of the French at Panama. Through these accounts stalks the indomitable figure of de Lesseps. "Pourtant ce réalisateur n'est pas un spécialiste, ni ingénieur, ni financier, ni administrateur; essentiellement—et c'est sans doute beaucoup plus difficile—il est l'animateur qui conçoit, met en oeuvre, exécute." How much the subsequent success of the American Government was due to the earlier French effort is made clear. There follow concise and clear descriptions of each canal and of its working. The nature of the traffic is then dealt with, and these sections are more than statistical summaries of tonnage and commodities.

The influence of each canal separately and of both together on world trade routes is the subject of several chapters. Toll charges, insurance rates, and possibilities of obtaining freight, prove more important than mileage in deciding whether a ship is to be sent through Suez or Panama or by some other route. In the case of Suez in particular there have always been alternatives. There are well-informed chapters on the defence of each canal. Who defends Suez must

perforce defend Egypt. Of Panama it may be said that its obvious strategic value to America just when she had acquired territorial interests in the Pacific was the chief motive for its construction. Yet, happily, both canals have always been open on equal terms to the shipping of all nations; and in preventing an attempt to gain special privileges for American shipping, Woodrow Wilson gave an exhibition of high statesmanship.

This book will prove important to all who take an interest in world affairs, while for the student of political and economic geography it is an essential study.

LL. R. J.

SEA-POWER AND EMPIRE. By F. J. C. HEARNSHAW. *London: George G. Harrap and Co.*, 1940. 9×6 *inches; 292 pages; maps.* 10*s* 6*d*

Professor Hearnshaw seeks in these lectures to impart freshness to the theme of sea-power in history by concentrating upon the relation between the command of the sea and the development of the British Empire. The earlier chapters cover the familiar ground of the age of discovery and of the struggles for supremacy with Spain, Holland, and France. He lays particular emphasis on the importance of British naval supremacy in the nineteenth century for the evolution of the Empire and for the economic development of Europe. His treatment of this aspect might have been carried further. The freedom of the seas ensured by the British Fleet in that century permitted the industrial development of Europe at the price of reliance upon overseas supplies of foodstuffs and also of many raw materials of modern industry drawn from tropical and subtropical countries. In return Britain drew an important invisible income from freights and overseas investments. The lure of this prize led in part to the unsuccessful German challenge in 1914–18, which was met by British continental commitments in support of the balance of power. The interesting question whether command of the sea without such intervention on land can maintain economic control is not discussed.

Interwoven with the narrative are details of the development of fighting ships, but except for some animadversions on naval operations in the war of 1914–18 and on the importance of Singapore there is little about strategy, and no reference to the possible effect of air-power. There are one or two mistakes in the reference to East Africa on p. 213: it should be remembered that the German pre-war (1914) colonies were not on the whole suitable for white colonization, and it is erroneous to suggest that vegetable oils and nuts from the tropics were not required by German industry.

G. R. C.

THE MONTHLY RECORD

LAND UTILIZATION SURVEY

The Land Utilization Survey of Britain is continuing the publication of the land-use maps on the 1-inch scale, and five sheets of the English series have recently been received. East Anglia is represented by the Ely and Bury St. Edmunds sheets, the north-east by Goole and Bridlington, and the south-east Midlands by Oxford, so that the range of types is comparatively wide. The method of compilation was described in the *Journal*, 78 (July 1931) 40. By the use of five colours and various symbols, sixteen classes of land-use are recorded. Most of the sheets include contrasting areas, for example, the Bridlington sheet covers the Lincolnshire Wolds and Holderness, and the Oxford sheet the chalk, the Greensand, and the clay belts. It will be appreciated that these maps afford no clue to the character or intensity of farming, or to the relative fertility of the soil. The classification "arable" includes of necessity rotation grass, so that at first sight the sheep areas of the Wolds and the predominantly arable Fens appear comparable. For an understanding of the character of the cultivation reference must be made to the county monographs in 'The Land of Britain' series, where changes in land-use are also discussed. It might be possible however to indicate summarily in the margins of the sheets the character of the "arable" classification. It is proposed to publish a generalized map of Great Britain in two sheets on the scale of 10 miles to the inch, and a preliminary attempt at a land-fertility map of England and Wales has been published in *Nature* (March 1939). Most of the survey was carried out in 1931 or 1932, with later corrections; it thus records the position at a critical stage in British farming, and will provide a basis for estimating the direction of present expansion.

LLYS HELIG

We have received from Dr. F. J. North a copy of his pamphlet, 'The legend of Llys Helig, its origin and its significance' (Suppl. to the *Proceedings*, Llandudno, Colwyn Bay and District Field Club, 1940). Llys Helig is the name given to a patch of seaweed-covered stones, one mile off the North Wales coast at Penmaenmawr, and visible at very low tides. There is a widespread popular belief that it is the remains of the palace of Helig ap Glannog, whose lands are said to have been lost by an extensive inundation at a date varying from the fourth to the ninth century A.D. Dr. North, accompanied by Mr. W. F. Grimes, who contributes an appendix on the archaeological aspect, examined these stones in August 1939, and sets out in this essay the results of his investigations into the character of the site and the origin and growth of the legend. The basis of the legend is shown to be a manuscript attributed to Sir John Wynn, dating from the early seventeenth century, which is known only through copies, and to which the misleading title "An ancient survey of Penmaenmawr" has been given. There is no mention by any contemporary chronicler of such a catastrophe, and the earliest reference to Helig and the overwhelming of his lands is in a thirteenth-century MS., though the site of the incident is not mentioned: nor does the story appear to have been known to seventeenth-century writers contemporary with Wynn. Dr. North gives reasons for thinking that the story is a piece of folklore transferred from the Cardigan Bay area, that the details and the precise location were invented by the writer of the 'Survey,' who probably built it around the existence of eroded Neolithic peat beds. Having shown the extremely confused and contradictory character of the historical evidence, Dr. North examines the recorded impressions of more recent observers, who believed that they could

trace the plan of the palace. He states that the whole area is covered with irregularly distributed stones, varying greatly in size and composition, in some places banked up higher than in others, and lying in wide, indefinite bands. That the latter appeared to some observers as the remains of sharply defined walls forming rectangular enclosures he attributes to the low angle of vision at which they viewed these bands. Mr. Grimes also concludes that the stones are of no archaeological significance.

From the standpoint of geology, Dr. North emphasizes the need to distinguish between the local evidence for coastal erosion and that for subsidence. The inundation envisaged by supporters of the legend would require a subsidence of about 40 feet, but there is no evidence for a marked downward movement in the last two thousand years. The patch of stones are in all probability the debris of a denuded hillock of boulder clay, the result of subsidence completed by the end of the Neolithic period.

PIONEERING IN THE PRAIRIE PROVINCES

In the eighth volume of "Canadian frontiers of settlement," entitled 'Pioneering in the Prairie Provinces: the social side of the settlement process,' the authors, Professor C. A. Dawson and Miss E. R. Younge, have assembled much information which should be useful to teachers seeking to give detail to descriptions of life on the Canadian prairies. After a brief discussion of the geographical environment and the course of settlement from the isolated farming of pre-railway days, they analyse the growth of population, racial distribution, and the development of city and smaller communal centres in Manitoba, Saskatchewan, and Alberta. The growth of population which began on a large scale about 1886, reached a climax in 1926 since when the rate has decreased; few immigrants now enter the region and there is a net loss of native born to other provinces. The British element represents 46·5 per cent. of the rural population and 67 per cent. of the urban. The absorption of foreign elements is proceeding markedly, though it is found that in the rural areas segregation contributes to stability and reduces clashes. With regard to social and economic centres, Winnipeg continues to serve the region as a whole; in the west Calgary and Edmonton, in establishing their predominance, have benefited from the growth of Vancouver as a trade centre for the Pacific and for the wheat traffic via the Panama Canal. The intermediate area is dominated by Regina and Saskatoon. It is emphasized that, despite forecasts, the smaller centres, often consisting of a few business establishments only, maintained their importance during the period 1910 to 1930.

The authors then give detailed descriptions of three typical communities; a small settlement on the fringe of the agricultural belt, a village centre of a farming district, mainly providing goods and services, and a small city. The "fringe" community, settled in the last twenty years, and comprising about sixty-five holdings cleared from the forest, has as yet scarcely advanced beyond the subsistence stage. The settlers come largely from the drought areas, and raise hay, wheat, potatoes, and dairy produce, the surplus of which is sold to new comers. Exchanges are largely effected by barter, the money in circulation being obtained by labour outside the community, or from government relief.

The most detailed part of the study of interest to geographers embodies the results of surveys of agricultural practice and conditions in four contrasted areas, classified as stable, transitional, pioneer, and "chronic fringe." The statistics include, among others, average areas of occupied and cropped land, percentages under various crops, amount of capital invested in land, machinery, etc., farm expenditure and income. The "chronic fringe" areas (Riding Mountain,

Manitoba, and Medicine Hat, Alberta) are defined as areas where after several decades farming is still a hazardous undertaking, largely owing to relief and variability of rainfall. In the Medicine Hat region, the characteristics are large farms (average occupied area 805 acres), low proportion of cropland (extensive farming; 58 per cent. of occupied area), a concentration upon one crop, wheat, and a relatively high proportion of capital invested in machinery. It is also, at first sight surprisingly, an area of high increase in net value of farms; the explanation probably being that only those farmers with exceptional enterprise, experience, and tenacity survive the successive periods of difficulties. In the stable area (*e.g.* Red River, Manitoba) wheat is also the predominant crop, but here, though the farms approach in size those of Medicine Hat, the proportion of cropped land is high (82 per cent.), more of the invested capital is represented by land, and, except for farmers of long standing, the increase of net worth is small, owing to high prices of land during wheat booms. In 1930 the total cash receipts per farm for Medicine Hat averaged 1766 dollars, for Red River 2145 dollars. All these varied conditions provide many problems in social organization, and these are discussed at length in the concluding chapters on education, religion, and health.

SOURCES OF ALUMINIUM

Dr. F. R. Cowper Reed has drawn our attention to the omission from the note on "Sources of aluminium" (in the August *Journal*, p. 150) of any reference to the great reserves of bauxite in the Gold Coast and Ashanti. These deposits were described by Sir Alfred Kitson in Bulletin No. 1 of the Gold Coast Survey, 1925. The deposits form caps from 10 to 40 feet thick on the summits of the highest flat-topped mountains in the country. The most important are on Mount Ejuanema, Kwahu, and on hills around Sefwi Bekwai in the western Gold Coast and Ashanti. The quantity of bauxite at Mount Ejuanema is estimated at 4 million tons, and in the Sefwi Bekwai area at over 33 million tons. According to the Gold Coast Handbook, none of these deposits were being worked in 1937, though with a reasonable reduction of freight charges, Sir Alfred had considered that the export of calcined bauxite from Ejuanema should prove profitable.

OBITUARY

BRIGADIER-GENERAL THE HON. CHARLES GRANVILLE BRUCE, M.V.O., C.B.

Charles Bruce was born in 1866, the third and youngest son of the first Lord Aberdare, who was for five years in the 'eighties President of our Society. From 1889 onwards he spent most of his military life at Abbottabad with the 5th Gurkha Rifles. The Kaghan valley was close at hand and made an admirable ground where he trained his Gurkhas on numerous expeditions. From 1890 until the outbreak of the war in 1914 all his leave in India was spent among the mountains; and "probably no man has had so wide a knowledge of the Himalaya".

In 1892 Bruce was with Conway in his expedition to the Karakoram. On arrival at Gilgit they explored the Bagrot valley and the further side of Rakaposhi; then marched to Hunza and thence to Nagar. From Nagar Conway sent him on to Hispar with instructions to cross the hitherto unclimbed Nushik La (17,000 feet) and bring up the expedition's spare baggage from Skardu to Askole; the task of cutting through the cornice near the summit of the pass was given to the two Gurkhas Bruce had brought with him. From Skardu he proceeded to Askole over the Skoro La (17,000 feet) still deep in winter snow and rejoined Conway. Advancing from Askole the party established their base camp near the head of the Baltoro glacier. Here they tried to climb the peak which Conway had called The Golden Throne; they failed, but were successful on the adjoining Pioneer Peak. The expedition then started to return to Baltistan, and on the way Bruce had an awkward accident while crossing a crevasse, resulting in a damaged back and a sprained leg. For ten days, of which two were passed without food, he had to lie on the glacier. Finally he and his Gurkha orderly managed to continue and were fortunate to meet a second Gurkha who had been sent ahead to bring back provisions. Only his magnificent physique and never-failing courage and cheerfulness carried him through.

Soon after Bruce's return to Abbottabad he was detailed for duty with Kashmir troops in Chilas, then very disturbed, and there was sharp fighting. In January 1893 he was one of the officers who accompanied Dr. G. S. Robertson to Chitral. The Shandur pass (12,000 feet) which was traversed *en route* was deep in snow, and Bruce made himself very useful in treating cases of incipient frostbite among members of the Sikh escort. In June 1893 he returned to Gilgit with Dr. Robertson; and then, for a short period, he was in charge of the Hunza-Nagar Scouts. I myself was then in political charge of Hunza-Nagar and was able to join Bruce in the mountains. I have very happy memories of these expeditions. He gave me and my Hunza orderly and his own Gurkha instruction in climbing, and I remember his strength, energy, cheerful temperament, and his tact in dealing with the local tribesmen.

During the winter of 1893 Bruce did some climbing on the Dhaola Dhar range, on which Dharmsala, the station of the 1st Gurkha Rifles, is situated. One of his companions on these climbs was Karbir of the 5th Gurkha Rifles, who with Amar Singh of the same regiment gave Conway so much assistance during his exploration of the Hispar, Biafo, and Baltoro glaciers, and early in 1894 accompanied him on his journey over the Alps from end to end. Bruce was the first to train Gurkhas for serious mountain work.

In 1894, while on leave in England, Bruce married a daughter of the late Sir Edward Campbell, Bart., and shortly after his return to India he was with the Gurkha Scouts operating in Waziristan under the command of Sir William

Lockhart. In 1895 he was in camp with Mrs. Bruce in the Kagan valley, and heard that Mummery, Collie, and Hastings were on their way to attempt Nanga Parbat. Mummery invited Bruce to join the expedition, and to bring two of his Gurkhas. Although he had not completely recovered from an attack of mumps, he immediately left for Kashmir, by the Shikar and Barbun passes, arranged for transport, went on to Abbottabad, obtained an extension of leave, and joined Mummery's party within a week of leaving his regiment. His leave expired, and he had left the party before the tragic disappearance of Mummery and the two Gurkhas.

In 1897 he served in the Tirah campaign against the Afridis, and at his suggestion the Gurkha scouts first wore shorts in this campaign. In the summer of 1898 he collected men from other Gurkha battalions and took them with the men he had trained in his own battalion for a tour in the easier Kashmir Himalaya and lower Ladakh for mountaineering training. Minor peaks were climbed, the first passage of the Sentik La was made, and the long glacier which descends from Nun Kun to the head of the Warwan valley was explored. From Kashmir the party returned to Abbottabad by the Kagan valley, traversing a peak of about 16,500 feet. On the tour in lower Ladakh he had fine views of the Baltistan mountains and main Karakoram chain; and shortly afterwards on the Singalila ridge, which divides Nepal from Sikkim, he could say that within six weeks he had seen the three highest summits in the world—Mount Everest, K_2, and Kangchenjunga.

In 1899 Bruce and Collie visited Switzerland and took with them Harkbir Thapa, Bruce's most efficient Gurkha. Later in the same summer Harkbir was also with them in Skye, where he astonished Macleod of Macleod by running from Sligachan Inn to the summit of Glamagi and back in faster time than the local ghillie's record.

In 1906, on leave in England, Bruce discussed with Dr. Longstaff and Mr. A. L. Mumm a plan to visit the region of Mount Everest and even for an attempt to climb the mountain. Lord Minto, the then Viceroy of India, and the Presidents of the Royal Geographical Society and the Alpine Club gave the three friends all possible encouragement, but the project was vetoed by Lord Morley, Secretary of State for India. The alternative of the Nanda Devi group was then chosen. They had two Italian guides, the brothers Brocherel, and one Swiss, M. Inderbinnen, and Bruce brought a number of Gurkhas, four of exceptional climbing merit and another a trained surveyor. Much interesting climbing was done by Longstaff, Bruce, the two Brocherels, and four Gurkhas in mastering the approaches to Trisul. Bruce had the misfortune to damage a knee, and was unable to share with Longstaff, the Brocherels, and Karbir their conquest of Trisul, but after recovery joined in exploring the Raikana glacier leading to Kamet, and in the passage of the Bhyundar pass leading to Badrinath.

In the winter of 1907 he paid his first visit to Nepal, and a second in the early months of 1914. He got permission to make a high-level tour round the northern sides of the Katmandu valley and to visit the small valley of Banepa some 15 miles to the east. During these visits to Nepal and Sikkim Bruce discovered the carrying powers of the Sherpas, who found loads of 100–140 lb. quite ordinary. He also found they stood extreme cold better than any other hill men he had met. In 1912 he visited the Kulu valley with Captain Todd of his regiment, Heinrich Führer, an Oberland guide, and a fresh batch of Gurkhas. For part of the six months he was disabled by a bad tumble; but the party's bag of peaks was about fifteen, of which some seven were round about 20,000 feet.

In July 1914 Bruce was commanding the 6th Gurkha Rifles and was with

them and the 5th in Gallipoli, where he was severely wounded. After hospital and convalescence in England he returned to India in 1916, was promoted Brigadier-General, and was given command of the Bannu brigade and the north Waziristan column operating against the Wazirs. He also took part in the Afghan campaign of 1919.

After two hot weathers at Bannu, one of the hottest stations on the frontier, his health broke down, and a medical board invalided him out of the Service, advising him to lead a quiet life in future as he was no longer fit for any great exertion. Thus in 1920 he retired from the Army after thirty-two years of distinguished service; and after consulting a doctor who was an old friend, he proceeded to Kumaon and Sikkim. In 1921 I was with those who accompanied Bruce from Saas Fee to unveil at the Britannia hut the memorial to the British members of the Swiss Alpine Club who had lost their lives in the war. On that occasion he appeared able to make the ascent as well as anyone in the party, and he continued to visit the Swiss Alps for at least ten years.

Bruce led the Mount Everest expeditions of 1922 and 1924, but was compelled on the latter to hand over to Major E. F. Norton at an early stage. He was adored by the Sherpa porters and, as Mr. F. S. Smythe wrote in 1934, "it was largely due to him that such an adventurous and loyal spirit has been fostered among the porters of the Everest Expeditions."

In 1923 he was elected President of the Alpine Club, and was several times President of the Mount Everest Committee. In 1915 he was awarded the Gill Memorial of the Society and in 1925 its Founder's Medal, for his lifelong geographical work in the exploration of the Himalaya, culminating in his leadership of the Mount Everest Expeditions of 1922 and 1924. He had been appointed a Member of the Victorian Order in 1903, and was made a Companion of the Order of the Bath in 1918. He received the Honorary Degree of D.Sc. from the Universities of Oxford and of Wales, the D.C.L. of Edinburgh, and the D.C.L. of St. Andrews.

B. E. M. GURDON.

WILLIAM LASHLY AND ERNEST MILLS JOYCE

The last few weeks have seen the death of two men whose strength of body and mastery of sledge technique have contributed very greatly to the success of British Antarctic exploration. Lashly worked for Scott, Joyce for both Scott and Shackleton, and the sledge journeys in which they took part are among the best ever accomplished.

William Lashly, who died on 12 June 1940, first served with Scott in the *Discovery* in 1901–4, and had the distinction with Edgar Evans of being with Scott on the Western Plateau journey in 1903–4; it was he who grimly held on to the sledge when Scott and Evans fell through a great crevasse and hung helpless in mid-air. Scott in his account of this great journey pays many tributes to Lashly's strength and character.

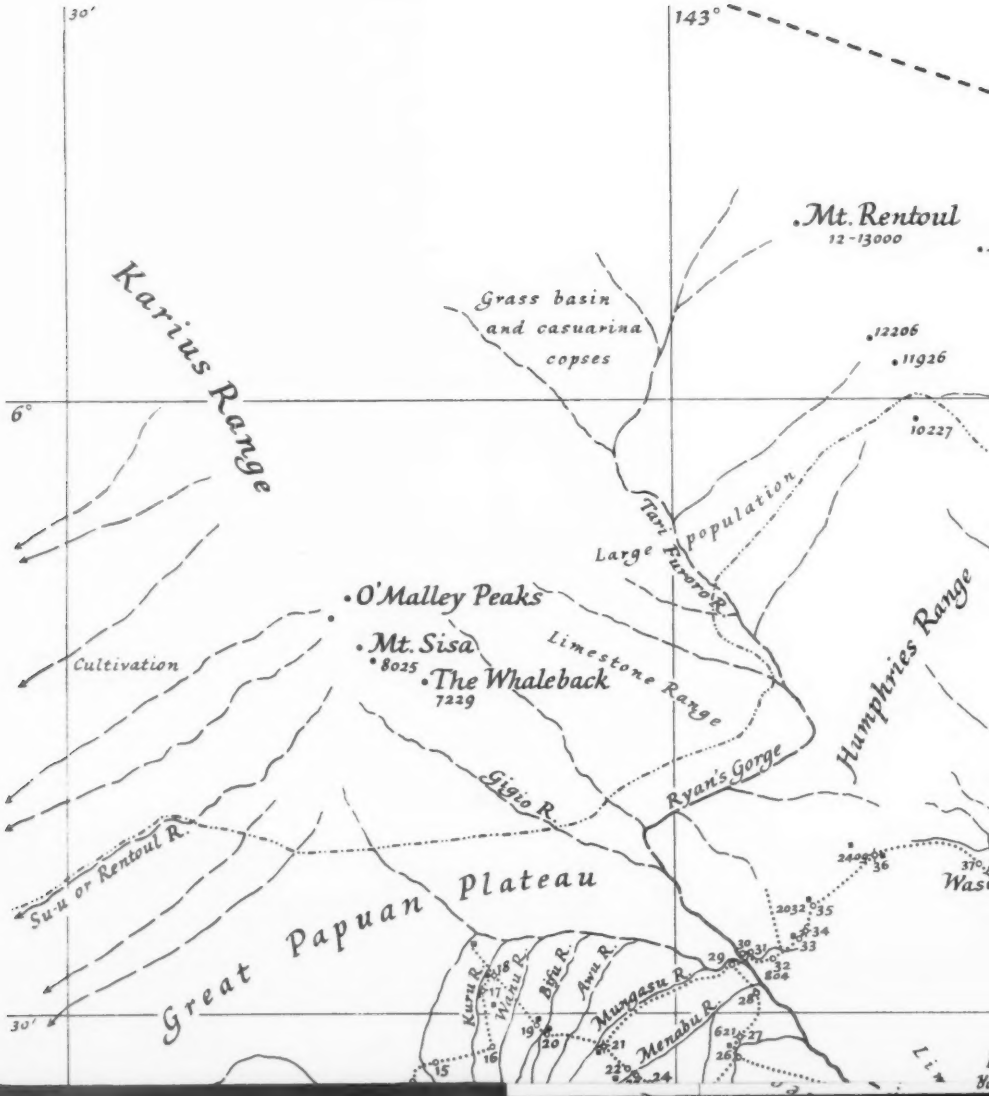
"Lashly, in appearance, was the most deceptive man I have ever seen. He was not above the ordinary height, nor did he look more than ordinarily broad, and yet he weighed 13 st. 8 lbs., and had one of the largest chest measurements in the ship. He had been a teetotaller and non-smoker all his life, and was never in anything but the hardest condition."

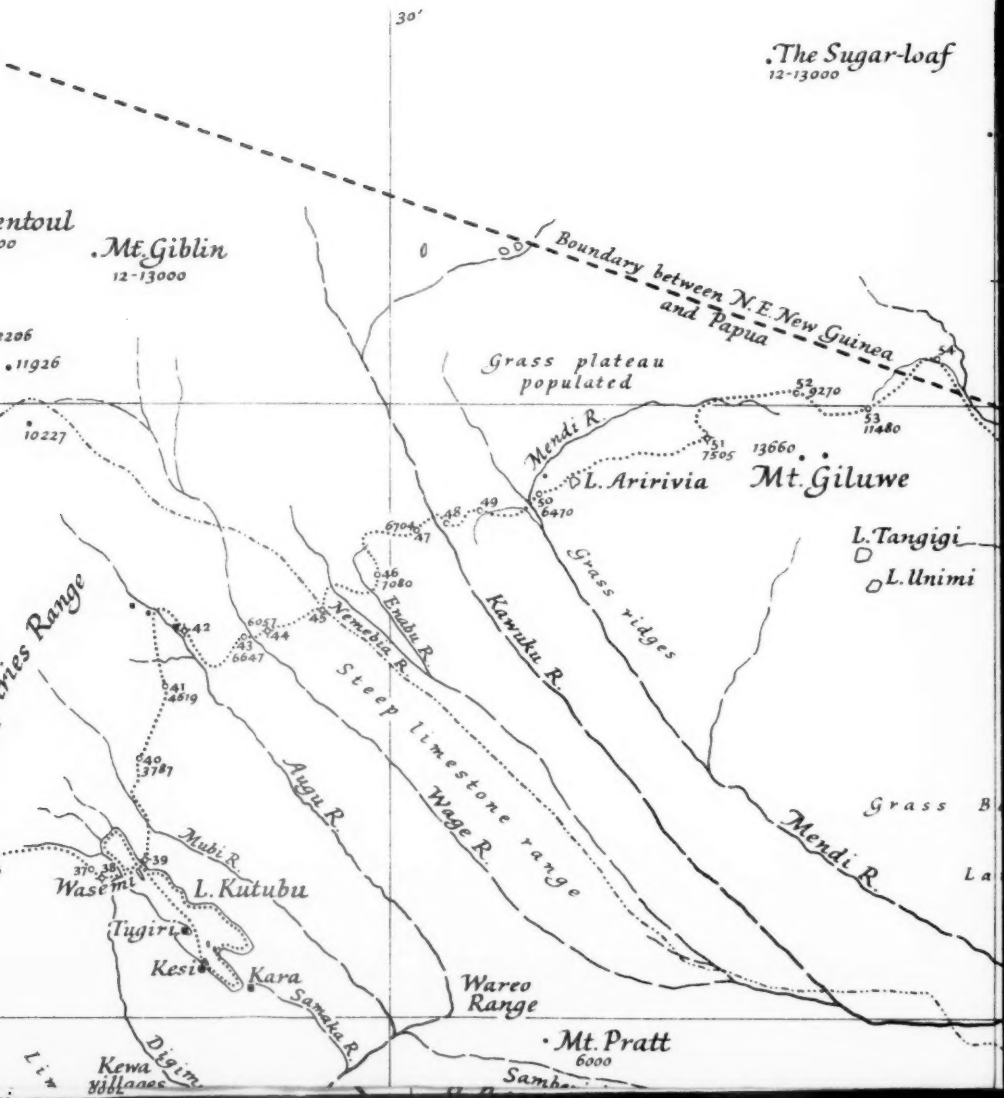
Lashly went south again in 1910, and a name which after the first expedition had only been familiar to an appreciative few was now to become widely known. Lashly was one of Scott's last supporting party under Lieut. E. R. G. R. Evans, the third member of the party being Tom Crean, another naval petty officer.

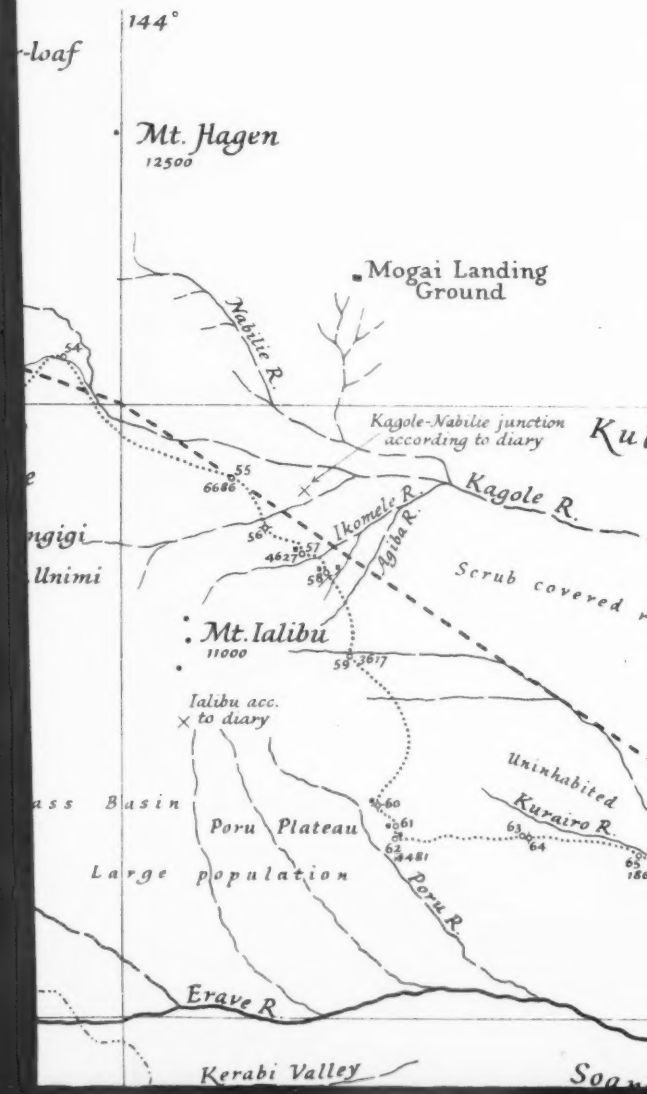
These three, who turned back at 87° 34′ S., were the last to see Scott and his companions alive. Trouble soon began for Evans' party, for the leader developed scurvy early on the return journey. At first he was able to struggle along on foot, but finally Lashly was obliged to take charge and place him on the sledge. Lashly kept a diary of the journey, and it gives the clearest picture of the writer's character, and of how he and Crean, true to their naval training, set about saving their leader's life. Many place Lashly's diary first among all Antarctic personal records. Long extracts appeared in Cherry-Garrard's 'The Worst Journey in the World,' and now within the last year the diary has been privately printed complete from 25 December 1911 to 22 February 1912. Men such as Lashly are rare. The keynotes of his character were honesty, loyalty, and simplicity. He was too modest to realize how far the strength both of leader and of expedition depended upon the presence among the rank and file of men like himself and his comrades of the mess decks.

Ernest Mills Joyce, who died on 2 May 1940, also began his Antarctic career in *Discovery* days. He sailed with Scott as an A.B., along with his close friend Frank Wild, and in the second year in the Ross Sea took part in the Barrier journey led by Lieut. Barne. A few years later Joyce and Wild were the two *Discovery* hands selected by Shackleton to go with him as sledge-masters in the *Nimrod* in 1907. He was on Shackleton's supporting party which turned back 35 miles south of Hut Point, Shackleton going on alone with his three companions from this point. Later in the season Joyce laid the Bluff Depot, and it was the finding of this depot by Shackleton which saved his party. Joyce had been disappointed at not being on the Farthest South party, but the finding of his depot miraged up was a decisive incident on that great journey, and his own great chance was still to come.

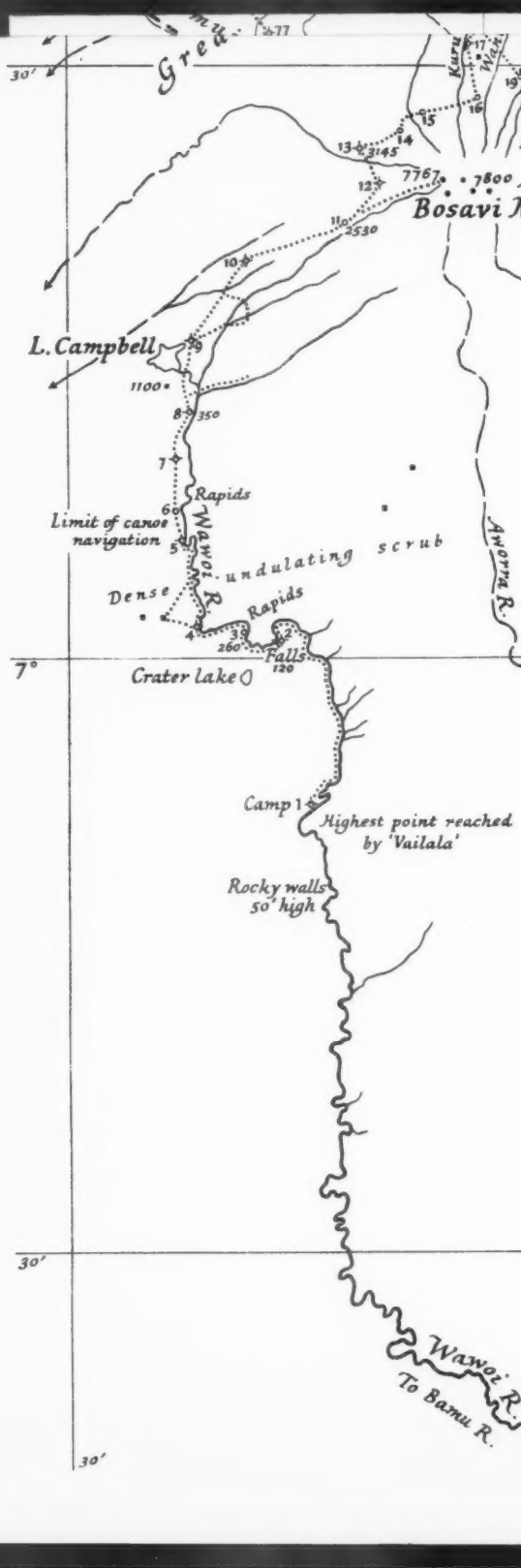
Joyce's sledging so far had been all man-hauling, but on his next expedition he was also to show himself a master with dogs. In 1914 Shackleton sent him as technical expert with Mackintosh's party to the Ross Sea. The main duty of this party was to lay a depot at the foot of the Beardmore Glacier which Shackleton would pick up after crossing the continent from the Weddell Sea. Joyce has himself told in 'The South Polar Trail' the story of the besetting of the *Aurora* and the marooning of the shore party on Ross Island with insufficient stores and with no sledging gear apart from that which could be salved from the old winter quarters of previous expeditions. Naturally enough, under these difficult conditions, sickness developed, the leader and two others going down with scurvy, and the task of laying the depot was carried out under immense difficulties by handicapped men. Finally Joyce, on whom the leadership of the party had devolved, laid the depot right at the foot of the Beardmore, and later also brought back two of the three scurvy cases to the Hut Point Base. Joyce's description of his own return to Hut Point, still keeping his dogs, is especially well worth reading. Here, in 1903, he had stood and cheered Scott returning from Farthest South after 93 days. Now he was back himself as leader of a party after a journey of 193 days. That long journey could only have been carried through by a man gifted with both toughness and determination. The laying of the Beardmore depot is Joyce's best monument and fine proof of his loyalty to his leader and strength on the trail. J. M. W.; R. E. P.


30'
143°
Mt. Rentoul
12-13000
Grass basin
and casuarina
copses
12206
11926
10227
Karius Range
6°
Tari Furoro R.
Large population
O'Malley Peaks
Mt. Sisa
8025
The Whaleback
7229
Limestone Range
Cultivation
Humphries Range
Gigio R.
Ryan's Gorge
Su-u or Rentoul R.
Great Papuan Plateau
Kuru R.
Wahu R.
Biri R.
Awu R.
Mungasu R.
Menabu R.
30'

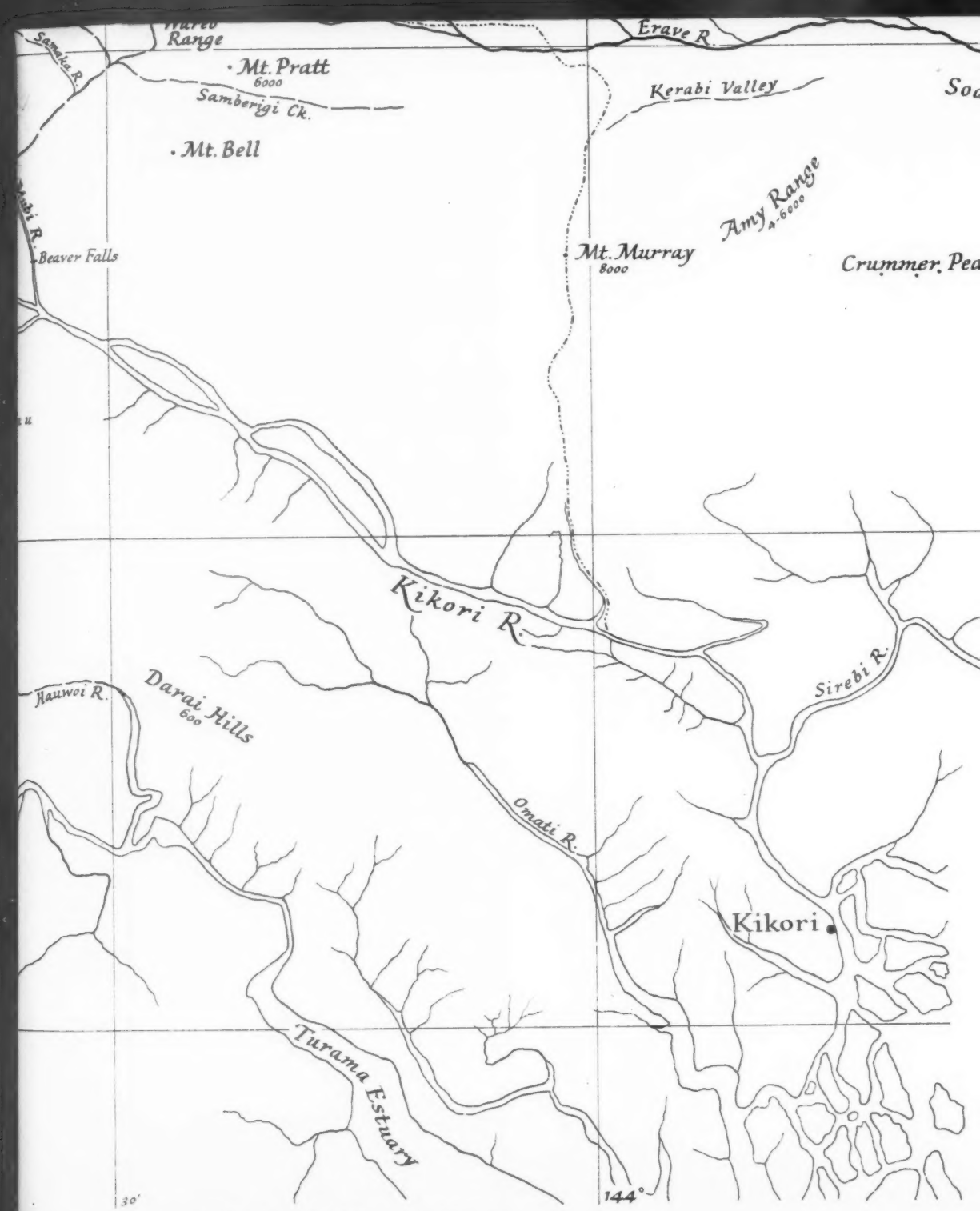

30'
.The Sugar-loaf
12-13000
.Mt.Giblin
12-13000
Boundary between N.E.New Guinea and Papua
Grass plateau populated
Mendi R.
L.Aririvia
Mt.Giluwe
13660
L.Tangigi
L.Unimi
Grass ridges
Kamuku R.
Nembia R.
Erubu R.
Steep limestone range
Augu R.
Wage R.
Mendi R.
Mubi R.
Wasemi
L.Kutubu
Tugiri
Kesi
Kara
Samaka R.
Wareo Range
Mt.Pratt
6000
Kewa villages
11926
10227
7505
6470
7080
6647
4819
3787
6704
6057
7270
11480
7505


144°
-loaf
Mt. Hagen
12500
Mogai Landing Ground
Nabilie R.
Kagole-Nabilie junction according to diary
Kagole R.
Ikomele R.
Agiba R.
Scrub covered
Unimi
Mt. Ialibu
11000
Ialibu acc. to diary
Uninhabited
Kurairo R.
Poru Plateau
Large population
Poru R.
Erave R.
Kerabi Valley

30'
145°
6°
Kubor Mts.
R.
overed ranges
Mt. Suauru
8744
Tive Plateau
Willi R.
rhabited
rairo R.
65
1866
66
67
68
69
70
71
72
73
2861
74
75
3091
Tu R.
76
1707
Karimui
77
30'
Mt. Karimui


30'
Great
Kura
Wara
19
16
15
14
13
3145
12
7767
7800
Bosavi M
11
2530
10
L. Campbell
1100
8
350
7
Rapids
6
Limit of canoe navigation
Wawoi R.
5
undulating scrub
Dense
Rapids
4
3
260'
Falls
120
Aworra R.
7°
Crater lake
Camp 1
Highest point reached by 'Vailala'
Rocky walls 50' high
30'
Wawoi R.
To Bamu R.
30'

Kuru
Mungasu
Menabu R.
Bosavi Mts.
7800
Limestone
Kewa villages
Digimu R.
Samaka R.
Hegigio R.
Mubi R.
Beaver Falls
Limestone plateau
heavily wooded
Awoma R.
Turama R.
Hauwoi R.
Wawoi R.
Bamu R.
Awoma R.
143°



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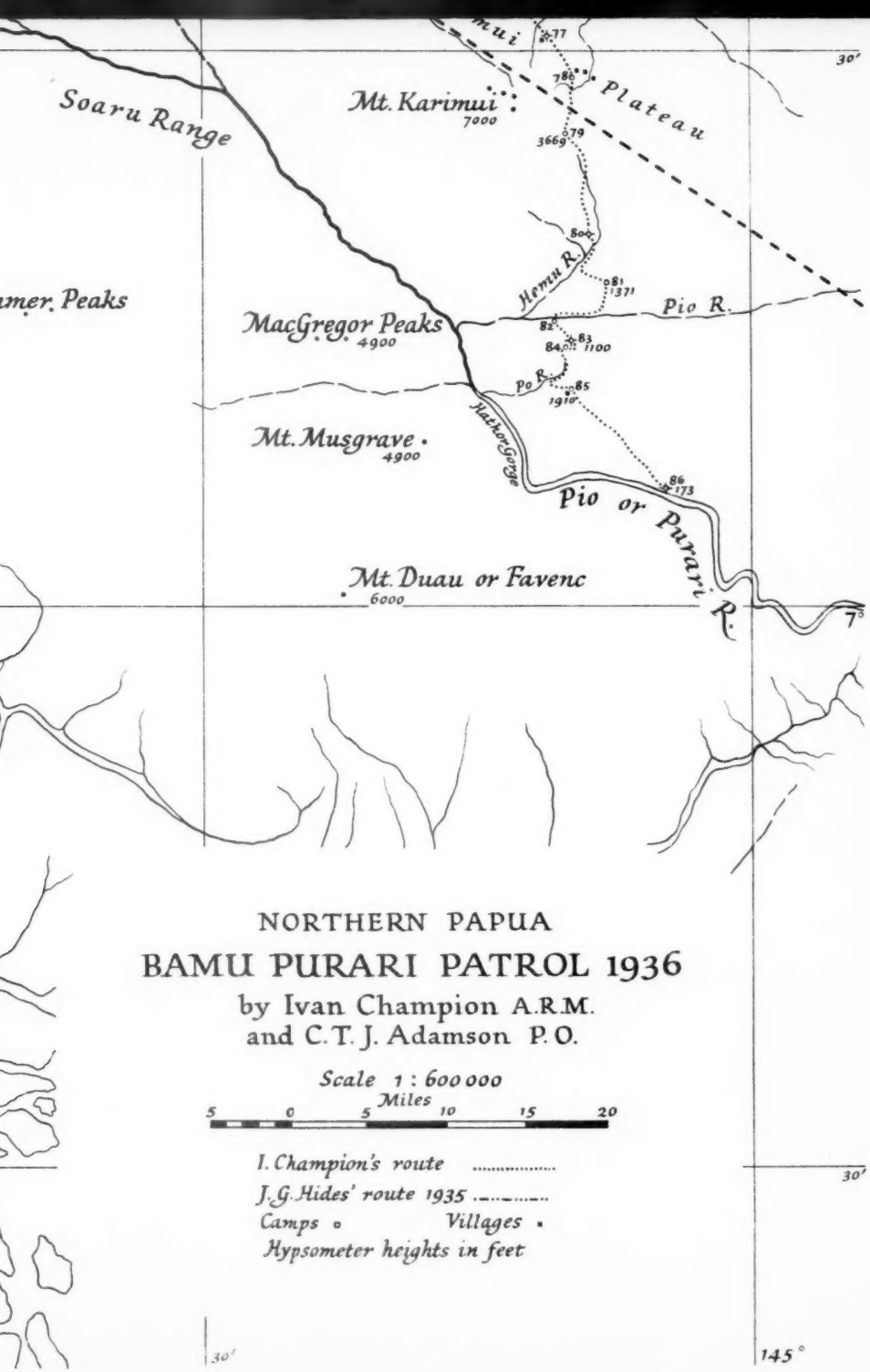

NORTHERN PAPUA

BAMU PURARI PATROL 1936

by Ivan Champion A.R.M.
and C.T.J. Adamson P.O.

Scale 1 : 600 000

Miles 5 0 5 10 15 20

I. Champion's route .....

J.G. Hides' route 1935 .-.-.-.-

Camps ○ Villages ▪

Hypsometer heights in feet

30'

145°

VOLVO 460 480

XI